DRAYSONIA

WORKS BY GENERAL DRAYSON

Practical Military Surveying

The Common Sights in the Heavens

The Last Glacial Epoch

Experiences of a Woolwich Professor

Thirty Thousand Years of the Earth's Past History, read by the Aid of the Discovery of the Second Rotation of the Earth

Untrodden Ground

Important Facts and Calculations for the Consideration of Astronomers and Geologists

Proper Motion of the Fixed Stars

Etc.

DRAYSONIA

BEING AN ATTEMPT TO EXPLAIN AND POPULARISE THE SYSTEM OF THE SECOND ROTATION OF THE EARTH

AS DISCOVERED BY THE LATE

MAJOR-GENERAL A. W. DRAYSON

F.R.A.S.

FOR FIFTEEN YEARS PROFESSOR ROYAL MILITARY ACADEMY, WOOLWICH

ALSO GIVING THE PROBABLE DATE AND DURATION OF THE LAST GLACIAL PERIOD, AND FURNISHING GENERAL DRAYSON'S DATA, FROM WHICH ANY PERSON OF ORDINARY MATHEMATICAL ABILITY IS ENABLED TO CALCULATE THE OBLIQUITY OF THE ECLIPTIC, THE PRECESSION OF THE EQUINOXES, AND THE RIGHT ASCENSION AND DECLINATION OF THE FIXED STARS FOR ANY YEAR, PAST, PRESENT, OR FUTURE

BY

ADMIRAL SIR ALGERNON F. R. DE HORSEY

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PREFACE

In the following treatise I have adopted the title 'Draysonia' in honour of a man whose scientific attainments have been but little known or recognised, whose death in September 1901 was a great loss to astronomical science, and who in future days will, I think, be acknowledged as having been a remarkable discoverer. I refer to the late Major-General Alfred Wilks Drayson, F.R.A.S., late Royal Artillery, who, in addition to distinguishing himself in his profession, was for fifteen years Professor, Royal Military Academy, Woolwich, and for two years attached to the Royal Observatory at Greenwich, author of *Practical Military Surveying*, *The Common Sights in the Heavens*, *The Last Glacial Epoch*, *Experiences of a Woolwich Professor*, *Thirty Thousand Years of the Earth's Past History*, read by the aid of the discovery of the second rotation of the earth, *Untrodden Ground*, *Important Facts and Calculations for the Consideration of Astronomers and Geologists*, *Proper Motion of the Fixed Stars*, etc.

I am fully aware of the difficulty of my task, and of how imperfectly I can do justice to Drayson in attempting to describe his system; indeed, I should not venture the attempt were it not that General Drayson, shortly before his death, repeatedly urged me to write upon the subject. Writing to me very shortly before his death, he said: 'The reason why I thought that you ought to write something is that it would be a loss to astronomical science if the accurate calculations which you have made were allowed to be buried in your work-book and among my papers. I refer especially to your

investigations to obtain the annual motion of the pole 20″·0529, the annual angle at C. 40″·8114, the zero year A.D. 2294·75, the cycle 31,756 years, the annual precession of the equinox in 1900, the annual diminution of the obliquity and the variable rate of this decrease.

'All these calculations are based on sound geometry.' In again urging me in his last touching letter before his death, when complaining bitterly of the unreasoning opposition he had encountered, he said: 'I have spent between two and three hundred pounds in getting my books, pamphlets, etc., published, and have received less than ten pounds in return. Money-making has not been my object, but that truths in nature should be made known. I can only claim to have done my best, though whether good results will follow I cannot say.' I also can only claim to have done my best.

My work in assisting Drayson began after reading his *Untrodden Ground*, and has been carried on almost entirely by letter. Drayson's letters to me amounted to three or four hundred, and were continued until his death. From this correspondence and from Drayson's works I learned a great deal, and found the occupation enthralling—too much so, for in working with Shortrede's admirable logarithms, which admit of accuracy to the $\frac{1}{10}$ of a second of arc and to $\frac{1}{100}$ of a second of time, up and into the small hours of the night, I considerably impaired my eyesight. I was induced to look into Drayson's system by my old and distinguished friend, the late Sir John Cowell, who, when on duty at Osborne, had lent Drayson's *Untrodden Ground* to H.R.H the then Crown Princess of Germany, afterwards the Empress Frederick, and told me how great an interest H.R.H. had taken in the matter. The subject also has engaged the attention of H.R.H. the Duke of Connaught, who, when at Woolwich Academy as a cadet, had studied under Drayson, and was thus aware of his great ability. I mention this as another instance of the

great interest always taken by members of our Royal Family in scientific matters.

I believe I have been a good scholar of Drayson's, judging from his kind appreciation of my efforts, for in an article of his some years ago in the *Yorkshire Post,* the following commendation appears : 'It is quite unnecessary for me to refer to the scientific attainments, especially in practical astronomy, possessed by Admiral de Horsey. In the Royal Navy these are well known. I may say, however, that during the fifteen years that I was Professor of Woolwich I looked over several thousand examination papers on various questions in practical astronomy which had been worked out by officers and cadets, who were excellent mathematicians, and to whom the practical working of spherical trigonometry was mere child's play, but in no single instance have I seen anything equal in accuracy and neatness to the work accomplished by Admiral de Horsey.'

The above flattering opinion of my attainments far exceed such abilities as I may possess, but I here insert it as a record of General Drayson's appreciation of the assistance I rendered him in astronomical computations from 1893 until that distinguished astronomer's death in 1901. Drayson's lamented death occurred without his receiving that public recognition of his scientific attainments and discoveries which he merited, and which I trust posterity will accord him.

A. F. R. DE HORSEY.

COWES, *March* 1911.

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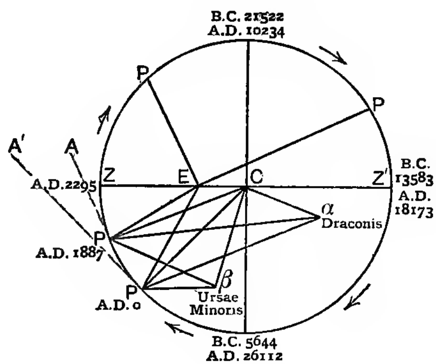
INTRODUCTION

DRAYSON'S SECOND ROTATION OF THE EARTH

'*E pur si muove.*'—GALILEO



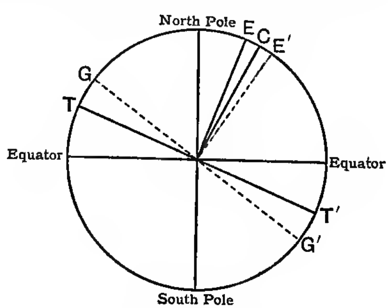
IN the above diagram the circle is intended to represent the path traced by the pole of the earth in its course round a cycle of 31,756 years with a radius of 29° 25′ 47″ from *C*, the centre of second rotation. *E* is the pole of the ecliptic distant about 6° from *C*. *Z*, which I have termed the zero year, is the position the pole will attain in A.D. 2295 when *E* and *C* are aligned; when the obliquity of the ecliptic will be at its minimum, and the earth therefore at the middle point of its temperate epoch. *Z′* represents the place the pole attained at the middle of the last Glacial Epoch, 13,583 B.C., when the obliquity of the ecliptic was about 35° 25′ 47″. *P* represents the pole of the earth at various periods, *PE* the obliquity of the ecliptic at various times, *Pa* the polar distance of (say) *a* Draconis, and the angle *CPa* the right ascension of that star, and *Ca* its distance from the pole of

second rotation. Similarly $P\beta$ is the polar distance of (say) β Ursæ Minoris, the angle $CP\beta$ is the right ascension of that star, and $C\beta$ is its distance from the centre of second rotation. The dotted line PA' shows the direction of the first point of Aries at the beginning of the Christian era, and PA its direction about the present time.

In describing the angles CPa and $CP\beta$ as the right ascensions of those stars, it should be added that they are so subject to + or — 6 h. or 18 h., as the case may be, and to a correction for standard of time in order to assimilate them to the recorded right ascensions in the Nautical Almanac, and to the Greenwich standard rate of sidereal time, as described in Section VII.

The following diagram is intended to show the position of the ecliptic and its pole at the mid-Glacial Period, when the obliquity of the ecliptic was about 35½°, as compared with their positions at the present or nearly mid-temperate period, in which the obliquity is about 23½°.

It will be observed that at the mid-Glacial Period the Arctic and the Antarctic circles come down to about latitude 54½°, and that the tropics of Cancer and Capricorn extend from the equator to about latitude 35½°.



EXPLANATION OF THE DIAGRAM

C is the centre of second rotation.
E the pole of the ecliptic at mid-temperate period.
TT' the ecliptic at mid-temperate period.
E' the pole of the ecliptic at mid-Glacial Period.
GG' the ecliptic at mid-Glacial Period.

The designation 'second rotation' of the earth may be open to objection, but it is the name given by Major-General Drayson, the author and discoverer of the system, which I shall endeavour to describe in these pages; it is therefore sufficient for my purpose. By whatever name the movement may be called, I refer to the revolution of the pole of the earth round a centre C in some 30,000 odd years, instead of, as orthodox astronomers describe it, round the pole of the ecliptic in about 25,867 years.

As I understand Drayson's system, it is founded (1) on the assumption that the stars, with some exceptions, are fixed; or that their movements, if any, are so small as to be inappreciable by observers on a planet so distant from the stars. (2) That, the stars being fixed, their apparent motions in right ascension and declination are alone due to the axis of the earth altering its inclination about $20''$ annually. (3) That this alteration in the inclination of the axis of the earth is a movement in a small circle at a radius of about $29° 25' 47''$ from a point in the celestial concave, which point is about $6° 0' 0''$ from the pole of the ecliptic, and situated as hereinafter described in at present about 18 h. right ascension.

Some professional astronomers, who may have done me the honour to read the above few lines, will then perhaps lay down my paper saying that the system appears to be founded on hypotheses which are not proved, and which are not in accordance with the long established teaching of our greatest astronomers. 'Read such and such a work at page so and so and you will see how erroneous are your views; we refuse to consider or even read arguments which are not founded on the dicta of our orthodox text-books.'

To those who thus reason I have no reply, unless it be to quote a line of Dante's Third Canto, *Non ragionam di lor, ma guarda e passa.* But the many deep thinkers whose reputation and emoluments are not dependent on adherence to orthodox text-books will perhaps read on, remembering that scientific truths are often arrived at from apparently unfounded hypotheses, the proof of which is brought about

by subsequent reasoning, and by the results of such reasoning coinciding with facts which could not exist on any other hypothesis than the one first suggested. If orthodox authority had alone been listened to, we should still have to admit that the earth was stationary, and that all the heavenly bodies revolved round the earth as a centre. I am not foolish enough to say of my very limited knowledge that Drayson's system is absolutely exact, but I do say that it appears to afford an easy means of calculating the obliquity of the ecliptic, the precession of the equinoxes, and the right ascension and declination of stars with preciseness for hundreds of years past or future, and that it provides a standard basis of time which will not, as at present, be always accumulating error. Can orthodox astronomers do any one of these things? Can it be claimed that the present system of time is correct, seeing that $3^{m}\ 3^{s}{\cdot}68$ of *purely imaginary time* were added in 1834, that Professor Stone finds a fresh accumulation of error of $41''{\cdot}51$ up to 1892, and that the best astronomers admitted the whole subject having fallen into confusion? General Drayson's system may be right or it may be wrong, but its results have shown ample cause for its careful and unprejudiced examination. If such examination should be accorded, and the results I have mentioned be shown to be correctly attained; and further, if with our present knowledge such results can be obtained by no other known method, surely this alone would go far to prove the correctness of his system. If English astronomical authorities continue to refuse it fair consideration, there is a danger of foreigners claiming to discover what Drayson asserted thirty or forty years ago. Already in a work recently published, entitled *Astronomie Populaire*, M. Flammarion says: 'C'est la Terre seule qui en est animée, et c'est elle qui accomplit pendant cette longue période une rotation oblique sur elle-même en sens contraire de son mouvement de rotation diurne.' This is precisely what Drayson stated some thirty years before Flammarion; in reply to which an astronomical authority informed him that if such was the case 'chaos would occur, and the earth

would be smashed up.' On this Drayson dryly observed that this was one of the objections urged against the daily rotation of the earth in former times.

The truth or fallacy of Drayson's system should be determined by astronomical research alone, but it is interesting to note that modern geology confirms that system which establishes with geometrical precision (not by mere inference, as geology teaches) the date of the last Glacial Epoch, showing that the coldest half of the cycle commenced about 23,423 years ago, reached its maximum about 15,484 years ago when the Arctic circle came down to about the latitude of Durham and the Antarctic circle to that of Tierra del Fuego, and terminated about 7545 years ago. This statement, published by Drayson twenty years before geologists would admit it, was ridiculed by them. In a late publication Drayson writes that at that time 'more than one distinguished authority stated that although he did not feel competent to criticise my astronomical and geometrical arguments, he could positively state that the dates I gave for the duration and termination of the Glacial Period were absurdly incorrect. He knew that the period terminated about a quarter of a million years ago, and lasted at least a million of years.'

'For every great advance in opposition to scientific authorities there must be a martyr; in former times this martyr was tortured or burned. In modern times he is ridiculed, contradicted, or ignored, then years after his death is given a statue.' I am inclined to believe with the late Sir John Cowell, and as a promising young officer of the Royal Engineers wrote to me some time ago, that within a generation, although probably not in Drayson's life, his system will be the accepted one of the text-books.

SECTION I

DRAYSON'S THEORY OF THE SECOND ROTATION OF THE POLE OF THE EARTH

As a preamble to the endeavour I am about to make to explain Drayson's theory of the second rotation of the pole of the earth, I perhaps cannot do better than reprint that which I wrote on the subject in June 1894, and which was published at the time in the Isle of Wight *County Press* and in the *Yorkshire Post*, together with a letter I had previously addressed to Major-General Drayson.

The Glacial Period as proved by the Second Rotation of the Earth

'A discovery of incalculable advantage to astronomy, although made and described in published works more than twenty years ago, appears to be still unacknowledged, and even branded as an absurd heresy, by some professional astronomers of the day. In order to add my humble efforts to induce qualified and unprejudiced persons to examine fully, test, and if true establish before all the world the truth of General Drayson's system, I propose to bring the matter as briefly as so large a subject will admit to the notice of those unacquainted with Drayson's works. For this purpose it is necessary first to touch upon certain fallacies of orthodox astronomy which seem to be almost universally accepted up to the present day.

'Sir John Herschel, in *Outlines of Astronomy*, stated that the pole of the heavens (*i.e.* the pole of the earth projected to the

celestial concave) describes a circle in the heavens round the pole of the ecliptic as a centre, at a constant distance of 23° 28′ in 25,868 years. (Since that was written it has been generally admitted that the distance between the two poles, *i.e.* the obliquity of the ecliptic, varies.)

'Sir George Airy, writing to Drayson in September 1870, says: "The direction of the movement of the terrestrial pole in any one year on the surface of the globe is at right angles to the great circle connecting the place of the terrestrial pole with the place of the ecliptic pole in that year." Again, in October 1870 the same great authority wrote to Drayson: "The state of matters regarding the pole of the earth and the pole of the ecliptic is this: the pole of the earth does not revolve round the pole of the ecliptic, in the sense in which you understand it. Supposing the poles connected by an arc of great circle, the pole of the ecliptic has a small motion in the direction of this arc towards the pole of the earth and a small motion transverse to it. The pole of the earth has no motion in the direction of the arc above mentioned, but has a large motion transverse to it. The distance between the two poles is not invariable." One can only describe the above statements as a mass of contradictions. If P did always move at right angles to E, it would be a geometrical absurdity to say the distance between the two varied.

'In April 1893 a very high authority wrote to me: "As a matter of fact, the pole of the ecliptic does not change its position in space by more than about one degree on either side of the mean, and the obliquity of the ecliptic will only vary to the same amount, one degree approximately on either side of the mean."

'Sir Robert Ball, Astronomer Royal of Ireland, in so late a work as *The Story of the Heavens* (1891), states that the pole of the earth moves in a circle, the centre of which is the pole of the ecliptic; and he illustrates this by a star map of Piazzi Smyth's, and gives 25,867 years as about the period of the cycle of precessional movement.

'Viewing the contradiction that the pole of the earth moves at right angles to the pole of the ecliptic, and yet alters its

distance (and putting aside the geometrical absurdity of a circle with a movable centre), it will be observed how hopelessly at sea the above authorities are upon the subject. Against their inexplicable theories Drayson asserts and proves geometrically that—

'1. The pole of the earth does not revolve in a circle with the pole of the ecliptic as a centre.

'2. The extent of variation of distance between the two poles is not limited to about 1°, its maximum variation being 12°.

'3. The pole of the earth describes a circle with a radius of 29° 25′ 47″ from a centre, which itself is 6° distant from the pole of the ecliptic.

'4. The period of the cycle of precessional movement is about 31,697 (since found to be 31,756) years, not 25,867 years, and the pole of the heavens traces a different path among the stars from that shown in Sir Robert Ball's *Story of the Heavens*.

'5. The last glacial period is proved to have commenced about 21,478 B.C., was at its height about 13,553 B.C., and terminated about 5629 B.C. At the height of the glacial period the obliquity of the ecliptic was 35° 25′ 47″, and consequently the arctic circle came down to about the latitude of Durham, and the antarctic circle to that of Tierra del Fuego.

'Having thus given some idea of existing orthodox theories and of their contradiction, I proceed to furnish a brief description of Drayson's system. For fuller details those who are interested in the subject should refer to Drayson's principal works, viz. *On the Proper Motion of the Fixed Stars*, *Thirty Thousand Years of the Earth's Past History* (Chapman & Hall), and *Untrodden Ground in Astronomy and Geology* (Kegan Paul & Co.); also to the published papers of Major-General Sir John Cowell.

'From a geometrical analysis of the curve traced by the pole of the earth during the past 1800 years, it proves to be an arc of a circle which has a radius of 29° 25′ 47″.

'The centre of the circle is located in the heavens in about

eighteen hours right ascension from the pole of the ecliptic, and is—

26°	37′	4″	from	*Alpha* Draconis.
9	17	38	,,	*Beta* Draconis.
10	24	41	,,	*Delta* Draconis.
21	50	12	,,	*Beta* Ursæ Minoris.
29	52	51	,,	Polaris.
27	55	7·3	,,	*Alpha* Cygni.
6	0	0	,,	Pole of Ecliptic.
29	25	47	,,	Pole of Earth.

'From the recorded observations of many years, it is known that the pole of the earth approaches stars having 0 hours right ascension about 20″·09 (since found to be 20″·0529) annually. This 20″·09 measured on a small circle is therefore the change in the position of the pole annually, and will be found equal to about 40″·89 (since found to be 40″·81143) on the great circle, viz. such is the annual angle at the centre of second rotation. Dividing the whole circle of 360° by 40″·89 will give about 31,697 (since found to be 31,756) years as the period of the entire revolution of the pole of the earth round the centre of second rotation.

'Such being in the briefest language a summary of Drayson's system of the second rotation of the earth, allow me to add a copy of a letter I lately addressed to General Drayson, giving the results of some of the tests I have applied to his system and of the inevitable conclusions to which, as an independent and totally uninterested critic (except so far as one is interested in searching after truth), I have arrived. I neither endorse nor advocate any theory, nor do I pretend to disclose all such parts of General Drayson's discovery as he has been good enough to entrust to me. He is rightly careful that no one should rob him of the credit justly due to him, and there are some points—now absolutely unknown to the scientific world—to which he alone can do justice, and which he will doubtless be prepared to make public property when an impartial tribunal, free from professional jealousy, has admitted the truth of his system. I merely give geometrical proofs by the

results of my calculations from data of many years back agreeing minutely with actual present Greenwich observations —results only now obtainable by constant observation, and which no astronomer can calculate until he accepts and uses Drayson's system. ALGERNON DE HORSEY.

'MELCOMBE HOUSE, COWES, *23rd April* 1894.

'DEAR GENERAL DRAYSON,—As you are aware, I have during several months been engaged testing by numerous calculations the accuracy, or otherwise, of your discovery of the second rotation of the earth. This pursuit has been of enthralling interest to me, and you may now like to know the result. Among these calculations (in all of which I have made no use of solar tables, or rate per year) were the following:—Starting from the date A.D. 2295·2, I calculated by your system what the obliquity of the ecliptic would be for the year 1885, working the problem by spherical geometry. On comparing my calculated obliquity with that recorded in the Nautical Almanac, I found a difference of only 0″·07. I then took the recorded R.A. and declination of the stars *eta* Ursæ Majoris and *alpha* Draconis from Bradley's Catalogue of 1st January 1755, and (as I have said for all cases, without making any use of the rate of change, now found only by perpetual observation) I calculated the R.A. and Decn. of these stars for the 1st January 1895. On comparing my results with those given in the Nautical Almanac, I found a difference, in 140 years, for *eta* Ursæ Majoris of only 0^{s}·063 in R.A. and 1″·66 in Decn., and for *alpha* Draconis 0^{s}·156 in R.A. and 1″·45 in Decn. Again, working *alpha* Draconis from 1755 to 1875 (120 years), I calculated its R.A. for 1875 to be 14 h. 1 m. 0·121 s., and declination plus 64° 58′ 25″·2. These results I could not compare with observations, as, the star being omitted from the 1875 Nautical Almanac, its position apparently was not known at Greenwich. Determined to apply a crucial test, I selected the stars *lambda* Ursæ Minoris close to the North Pole, and *sigma* Octantis close to the South Pole, stars having an annual variation in R.A.

respectively twenty-fold and thirty-six-fold as great as the average. Calculating *lambda* Ursæ Minoris from 1850, I found its R.A. and Decn. in 1895 to be within $0^{s}\cdot249$ and $0''\cdot065$ respectively of the results by observation (and by rule of thumb for four years in advance) recorded in the Nautical Almanac. Then, calculating *sigma* Octantis from 1875, I found its R.A. and Decn. for 1895 to be within $4^{s}\cdot251$ and $0''\cdot28$ respectively of the Nautical Almanac record. Astronomers will think little of a difference of R.A. $4\frac{1}{2}^{s}$ in the case of a star which, in the twenty years, changed 2141^{s}, and which, being within 44′ of the pole, must hang on the wires of the transit instrument for a considerable time.

'I am fully aware that the above calculations are unknown to all astronomers to whom you have not explained your system. They are problems which any one with ordinary mathematical ability can work, if he knows your system. Without this knowledge, and without accepting your discovery to be true, I believe no living man can work them. To the Astronomer Royal to the Royal Astronomical Society, and to all the learned professors in the four quarters of the globe who adhere to their text-book knowledge, I believe these problems to be as insoluble as they would have been to Lobengula's medicine man. I am of a rather sceptical turn of mind, deeming that when in search of scientific truth one should take nothing on trust. As you know, there are two or three minor points in one of your published works in which I differ in opinion—perhaps owing to my incompetence, possibly owing to your having been mistaken—but these are trifles. With regard to your system of the second rotation of the earth, if one or two calculations only had agreed with observation, I should have said it was very extraordinary, but might possibly be a coincidence. But when I find that in no single instance has calculation failed to obtain results which are true, and which are unobtainable by calculation from any theory differing from your system; when I find that by your great discovery, and by the system you have founded thereon, I am enabled to calculate with precision the obliquity of the ecliptic, the precession of the equinoxes, and the polar

distances and right ascensions of stars for 5, 50, 500 or more years past or future; when I find that a precise and unchangeable standard of time is obtainable from your systems for all time to come instead of the present erroneous measure, instead of the "confusion" admitted by Sir John Herschel, and the muddle in which all astronomers now appear to be on the question of time (for instance, that distinguished astronomer, Mr. Stone, now Radcliffe Observer at Oxford, has within the last few months discovered an error of 41″·51); when, again, I consider that your system establishes the period of successive glacial epochs and the date of the last one—this, with geometrical precision, not by mere inference, as geology teaches; and when we note that modern geologists—forsaking their former theories about hundreds of thousands, or even millions, of years having elapsed since the last glacial epoch—now, years after your published demonstration of the fact, fix the period in accordance with your geometrical proof—when all the above results are considered, I can come but to one conclusion, viz. that the truth of your system is established beyond all doubt, and that this truth must shortly force itself on the scientific world.

'It is inconceivable to me that the Royal Astronomical Society has not enthusiastically taken up a subject which gives such strong evidence of its truth. To sift such a matter—a matter affecting the basis of all astronomical calculation—to the bottom is surely the first duty of a learned society which has the privilege of the prefix "Royal." I should have imagined—as I believe you did—that you had only to whisper 29° 25′ 47″ in order to put astronomers on the *qui vive* to elucidate a discovery of enthralling interest, which, for a chaos of supposed proper motions of millions of stars, substitutes a simple movement of the instrument (the earth), by which and from which all astronomical observations are made.

'History repeats itself. As some 260 years ago Galileo endeavoured to revive the Copernican system of 1543, and explained the apparent diurnal revolution of all the heavenly bodies by the simple, but then unacknowledged, fact of the earth's daily rotation, so you in the present day explain the

absurdity of ascribing complicated so-called proper motion to the stars by the simple fact of the second rotation of the earth round a fixed point distant from the pole 29° 25′ 47″, a fact you prove by calculating results which observations show to be true, and which no astronomer who adheres to the existing orthodox, but erroneous, theory can accomplish.

'You will probably not be imprisoned nor made to swear on your knees that your system is not true; you will not even be made to repeat once a week for the remainder of your life the seven penitential Psalms, but it would seem that—as in the days of Copernicus and Galileo—you have the learned societies against you for a time. You will have been both amused and interested in reading in the R.A.S. notices of the 9th March last Mr. Stone's discovery that the sidereal time of mean noon in 1892 was erroneous to the extent of $41^{s}\cdot51$. Mr. Stone—clever astronomer as he undoubtedly is—has probably little knowledge of, and no belief in, your system, and is perfectly innocent of the fact that the result of his labours is an additional confirmation of the truth of your system. Since the authorities at Greenwich in 1834 fudged in $3^{m}\ 3^{s}\cdot68$ of imaginary time to make their theories coincide with facts, the process has, I believe, not been repeated. The error therefore, which Mr. Stone dates from the introduction of Le Verrier's solar tables in 1864, has probably been accumulating ever since the time was corrected in 1834. On reading Mr. Stone's paper I at once calculated by your system what would be the accumulated error of the erroneous Greenwich system from 1834 to 1892, and I made it agree within a small fraction of a second of Mr. Stone's result. I observe that Professor Simon Newcomb disputes Mr. Stone's accuracy, but no doubt Mr. Stone is right.—Sincerely yours,

'Algernon de Horsey, Admiral.'

'Since writing the above I have tested Drayson's system conversely, *i.e.* totally ignoring his data and working only from observed positions of stars as recorded in the Nautical Almanac—data which no one can dispute—I calculated by my own independent method the radius of the circle described

by the pole of the earth, the annual motion of the pole, the angular distance between the poles of second rotation and ecliptic, and other fundamental items, bringing my results out to agree with Drayson's data with sufficient accuracy to confirm their truth. This I did by six different calculations, viz. with Polaris, *beta* Orionis, two of *alpha* Draconis, and two of *alpha* Virginis. These tests are to my mind conclusive, because their results could not all coincide with Drayson's data if the latter were not correct.

The statement in the foregoing article, that the period of one complete cycle of precessional movement is about 31,697 years, and the consequent apparent periodicity of the glacial epoch is, I understand, qualified by General Drayson to the following extent, viz.:—It is the periodicity corresponding to the *present* motion of the pole, and such it has been for centuries. But if any convulsion of nature, either in the past or in the future, should alter the position of the earth's centre of gravity, the gyratory motion of the pole, and therefore the periodicity and intensity of the Ice Age, would be different.

'A. de H.

'*January* 1895.'

In the above description of Drayson's theory I have alluded to some points which he rightly withheld from publication, but which are now public property. I refer to his method of measuring sidereal time. From Drayson's system it appears that by the orthodox doctrine that the pole of the earth moves round the pole of the ecliptic an error of time creeps in, and amounts at the present time to about $0^{s}\cdot7$ per annum, which error, if error it be, is entirely obviated by acceptance of Drayson's system of the pole of the earth revolving round the central point herein described. An annual difference of $0^{s}\cdot7$ sounds little, but has to be taken into account in all geometrical calculations wherein the right ascension is a factor. This alteration in the annual rate of sidereal time is a discovery of Drayson's which he wisely kept back from his published works and communicated alone to the late Sir John Cowell and to myself. This difference of rate of

time is not the least important of Drayson's discoveries. In a letter to me in January 1894, Drayson writes: 'When you have made this problem your own you will know that you are in possession of that which the astronomers of the whole world have never even dreamed of.' If it be assumed that Sir John Herschel's addition of 'purely imaginary time' of 3^{m} $3^{s}{\cdot}68$ was correct, it follows that under Drayson's system an error of some magnitude will under the Greenwich system have to be corrected. A short time ago I ventured to write to the late Astronomer Royal, Sir William Christie, to ask if I was right in my computation that an error in 1910 amounted to about 54 sec. I also told him that for the year 1892 I had made the error $41^{s}{\cdot}283$, and that I had observed that Mr. Stone had made it $41^{s}{\cdot}54$. I hardly expected a reply from so busy a man; but Sir William Christie very kindly replied at some length, to the effect that it was not considered there was any error, and that Mr. Stone had been mistaken in supposing one to exist. This subject will be more fully explained under its proper head in Section VII.

SECTION II

RADIUS OF SECOND ROTATION

I CAN scarcely do justice to General Drayson in attempting to describe how he determined the radius of second rotation to be 29° 25′ 47″ or thereabouts, but must endeavour to do so. He appears to have been impressed many years ago by ascertaining from the records that the obliquity of the ecliptic was not a fixed amount, as shown by the following:

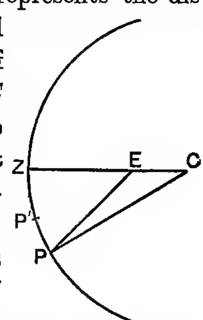
Date.	Recorder.	Obliquity.		
A.D. 30	Strabo Proclus, etc. .	24°	0′	0″
140	Ptolemy . . .	23	50	0
390	Pappus . . .	23	50	0
1437	Ulugh Beigh . .	23	31	58
1672	Cassini . . .	23	29	0
1690	Flamstead . .	23	28	48
,,	With correct refraction	23	29	2·5
1750	Lacaille . . .	23	28	19
1755	Bradley . . .	23	28	17·6
1800	Maskelyne . .	23	27	56·6
,,	Bessel . . .	23	27	54·78
1840	Airy	23	27	36·5
1860	Nautical Almanac .	23	27	27·38
1870	,, ,, .	23	27	22·2
1873	,, ,, .	23	27	20·88
1890	,, ,, .	23	27	12·79

From the above records it appears that the obliquity had been decreasing at a diminishing rate, and that in consequence the circle described by the pole could not be round the pole of the ecliptic as a centre, and must be round some other

point in the heavens. Drayson also contended that the seasons in respect to their intensity of cold and heat must be dependent on the amount of the obliquity of the ecliptic; it was impossible to explain the reason of there having been what is termed a glacial epoch except by a considerable increase of the obliquity beyond its present amount.

Assuming the stars, with possible exceptions, to be fixed, and that their apparent alterations of right ascension and declination can be fully accounted for by one simple motion of the pole of the earth, Drayson carefully studied the annual increase or decrease of their right ascension and declination as found by observation at Greenwich, and as recorded in the Nautical Almanac, and especially the amount of annual variation in right ascensions 15 h. and 21 h. Drayson concluded therefrom that the centre of rotation in order to cause those changes must be in right ascension about 18 h. and in declination about 60°. He then through a long course of years made innumerable calculations to find what distance between the pole of the ecliptic and his supposed centre of rotation would enable him to calculate from the best recorded obliquities in former years the obliquity for all other years, trying with distances *CE* varying between 5° and 7°, and by repeated trial and error, until he concluded that the radius *CP* must be about 29° 25′ 47″ and the arc *EC* about 6°.

Thus in the annexed diagram, in which *EP* is the obliquity when the pole is at *P*, and in which *CE* represents the distance between the centre of rotation and pole of the ecliptic, *CP* the radius of second rotation and with the angle *PCE* known, Drayson found himself able to calculate the obliquity *EP* with great accuracy for all other years and consequent different positions of *P*.



The other basis of Drayson's system is the annual motion of the pole, viz. *PP′* in the diagram — this always on the assumption that the principal stars are fixed, as he gathered from a close study of their annual variations recorded in the

Nautical Almanac, especially of those stars having a right ascension within an hour of 0 h. and 12 h., from which he at first roughly took the annual motion to be 20″·1 and subsequently 20″·09, but of late years accepted my perhaps more complete calculation of 20″·0529, which I ascertained by the method shown in Section III.

I fear the above explanation of Drayson's long labours to find his data is but a poor abbreviation; but in order to confirm Drayson's data, it occurred to me in 1894 that as his data enabled him accurately to calculate the obliquities and positions of stars as recorded in the Nautical Almanac, it should follow that conversely Drayson's data, if correct, should be ascertainable from authentic Nautical Almanac records. I accordingly made six independent calculations from orthodox records of the positions of stars at different periods, viz. two of *α* Draconis, one of each *α* Ursæ Minoris and *β* Orionis, and two of *α* Virginis, with the object of finding the value of *CP* the radius of Drayson's cycle, *PP′* the annual motion of the pole, and other resulting data. The mean of my six results made *CP* 29° 29′ 15″·31 and *PP′* 20·0754, to the precise accuracy of which I do not pretend, but which go far to establish the general truth of Drayson's system. A fuller account of these calculations, with a table of their results, will be given in Section VIII.

For more complete information about Drayson's method of finding his data, reference should be made to his publications mentioned in the preface to this work.

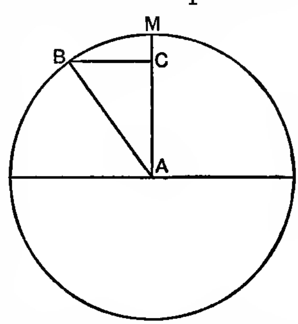
SECTION III

THE ANNUAL MOTION OF THE POLE

In the Nautical Almanac 1895, in the table of mean places of stars, only annual variation of stars' right ascension and declination was given, whereas in the Nautical Almanac of 1898 two columns are inserted against both the right ascensions and declinations, respectively headed annual precession and annual proper motion, from which it appears that the additional columns of proper motion were made between the two years named. As, however, the annual precessions are presumably obtained by observations at Greenwich, it may perhaps be assumed that the amount of precession includes the proper motion, and that therefore, in ascertaining the annual motion of the pole by the following method, no account need be taken of the proper motion, if any.

To find annual motion of pole from mean of annual precession (say) in Nautical Almanac of 1898.

In the accompanying diagram let AC=annual precession of a star within one hour of 0 h. or 12 h. right ascension, and let $AM=AB$=annual motion of pole $= \dfrac{AC}{\sin A}$ where the angle A is the amount of right ascension of the star from the meridian 0 h. or 12 h.



By the expression $AM = \dfrac{AC}{\sin A}$ the annual motion of the pole has been computed for every star in the Nautical Almanac of 1898 (seventy-three in number) which is within one hour

of 0 h. and 12 h. of right ascension, the results being shown in the table at the end of this Section. It will be seen that the mean of the results from the thirty-two stars which are within one hour of right ascension 0 h. is 20″·052678, and the mean of the forty-one stars within one hour of right ascension 12 h. is 20″·053105. The mean of the results from the whole seventy-three stars will be found to be 20″·052918, say 20″·0529, which by a curious coincidence is precisely the amount of aberration given by Peters, but how arrived at is beyond my knowledge.

If it be granted that the above method of finding the annual motion of the pole is fairly accurate, there is a corollary which is not without interest. Since $AM = \frac{AC}{\sin A}$ it follows that $AC = AM \times \sin A$, and that $\sin A = \frac{AC}{AM}$. This means that with the annual motion of the pole ascertained to be 20″·0529, either the annual precession in declination can be found from the star's right ascension, or the right ascension can be found from the precession in declination.

In the above computation for finding the annual motion of the pole I have for obvious reasons only taken stars within one hour of the equinoxial colure. I may, however, observe that the expression $AM = \frac{AC}{\sin A}$ applies equally to stars whatever their amount of right ascension. For example, I take at random the star η Centauri, whose right ascension is given in the Nautical Almanac of 1898 as 14 h. 29 m. 1^{s}·743. Let it be required to find that star's annual precession in declination from the expression $AC = AM \times \sin A$.

Log AM . . .	1·3021772
Log sin right ascension	9·9008594
Log precession . .	1·2030366
Whence precession .	=15·96014
,, by Nautical Almanac	15·958
Difference . . .	0·00214

This difference of less than $\frac{3}{1000}$ of a second of arc is negligible, and its smallness tends to prove either the accuracy of the Nautical Almanac or that of the ascertained annual motion of the pole, or the accuracy of both.

Possibly I shall be told that I have found a mare's nest, and that it has been known all along that the right ascension of a star and its annual precession in declination are functions of the annual motion of the pole, and that such motion can be found in the Nautical Almanac, and is properly termed aberration. It may be so, but I have failed to find any information on the subject in Herschel's *Outlines of Astronomy*, or other text-books, or in the explanations in the Nautical Almanac. I venture to think that the term aberration is not a happy one. Some of us may suffer from aberration of intellect; perhaps I do. My dictionary describes it as 'alienation of mind,' but there is no aberration in the works of the Great Architect of the universe. His laws are precise and immutable.

In concluding this section on the annual motion of the pole, I may say that strong reasoning would be required to shake my belief in Drayson's assertion of about forty-five years ago, and confirmed by the French astronomer Flammarion some thirty years after Drayson, as stated in the Introduction of this work: that the one single motion of the pole of the earth is, with certain exceptions, the sole cause of the apparent motion of the stars. Let us hope that this will not be claimed as a French discovery, but be rightly awarded to Drayson.

As an additional proof that the one single motion of the pole is the cause of the apparent precession of stars in right ascension and declination, I append* a diagram of the northern hemisphere, copied from an original one of General Drayson's, which purports to show that whilst the centre of second rotation (*C*) is a fixed point, *P*, the pole of the earth, has moved on an arc with *C* as a centre from *P* to *P′* between the time of the astronomer Ptolemy A.D. 140 and A.D. 1895, and that this motion of the pole has caused the so-called

* See diagram at end of book.

first point of Aries to alter its position about 20°, thus giving the stars an apparent motion in right ascension and declination, whilst in truth they have not moved. The effect of this one motion of the pole and of the change in the first point of Aries may perhaps be compared to that of a dial in which the numbers representing the hours (not the dial) have been slowly turning in the direction of the hands of a watch, and so have changed their position about 20° in a period approaching twenty centuries.

In the diagram referred to the numerous small arcs marked from Z to Z' approximately show the apparent alteration of the right ascension and declination of stars at such points, whereas in truth it is the zenith of such stars, not the stars themselves, which have moved. To be more exact, the curves show the direction rather than the correct amount of the movement, owing to the protraction of a portion of a sphere on a flat surface and the distortion arising therefrom. A reference to the precessional movement in the table of fixed stars in the Nautical Almanac will, I think, show the general accuracy of the apparent motion thus depicted in the diagram. The truth of this appears incontestable when it is considered that the otherwise unaccounted for and variable changes in the positions of myriads of stars are all exactly explained by the one annual motion of the pole of the earth.

I am very sensible of the imperfection of my explanation of Drayson's diagram, and can only hope that in the future the subject will be more fully considered and better justice done to him by those more capable than myself.

Annual Motion of Pole deduced from Annual Precession in Declination in 1898 Nautical Almanac

Star's Name.	Right Ascension.	Annual Precession.	Annual Motion of Pole of the Earth.
	h. m. s.	″	″
C^2 Aquarii	23 4 0·5	19·458	20·0535
γ Toucani	23 11 28·6	19·605	20·0528
γ Piscium	23 11 52·6	19·613	20·0535
κ Piscium	23 21 42·2	19·774	20·0533
B.A.C. 8213	23 27 48·6	19·856	20·0535
ι Phœnicis	23 29 35·3	19·877	20·0533
ι Piscium	23 34 42·1	19·931	20·0530
γ Cephei	23 35 9·4	19·945	20·0628
δ Sculptoris	23 43 36·8	20·001	20·0522
27 Piscium	23 53 27·0	20·045	20·0532
ω Piscium	23 54 4·3	20·046	20·0527
2 Ceti	23 58 30·9	20·052	20·0524
a Andromedæ	0 3 6·8	20·051	20·0528
β Cassiopeiæ	0 3 43·9	20·051	20·0537
γ Pegasi	0 7 58·9	20·041	20·0532
o Octantis	0 12 31·8	20·020	20·0500
ι Ceti	0 14 13·8	20·013	20·0516
ζ Toucani	0 14 45·4	20·010	20·0516
44 Piscium	0 20 10·4	19·975	20·0526
β Hydri	0 20 23·8	19·970	20·0494
a Phœnicis	0 21 14·5	19·965	20·0511
12 Ceti	0 24 49·9	19·935	20·0526
ϵ Andromedæ	0 33 9·8	19·842	20·0516
δ Andromedæ	0 33 52·2	19·834	20·0526
a Cassiopeiæ	0 34 42·9	19·824	20·0536
β Ceti	0 38 28·2	19·772	20·0539
δ Piscium	0 43 23·3	19·694	20·0523
20 Ceti	0 47 47·6	19·617	20·0514
γ Cassiopeiæ	0 50 32·9	19·566	20·0517
μ Andromedæ	0 51 5·2	19·556	20·0521
a Sculptoris	0 53 41·5	19·503	20·0507
ϵ Piscium	0 57 38·9	19·420	20·0510
η Octantis	11 0 1·3	19·371	20·0538
4 Ursæ Majoris	11 3 55·8	19·457	20·0542
β Crateris	11 6 38·4	19·511	20·0520
δ Leonis	11 8 41·1	19·553	20·0536

Star's Name.	Right Ascension.	Annual Precession.	Annual Motion of Pole of the Earth.
	h. m. s.	″	″
θ Leonis	11 8 53·3	19·556	20·0526
δ Crateris	11 14 14·4	19·654	20·0524
τ Leonis	11 22 41·5	19·789	20·0541
λ Draconis	11 25 21·1	19·823	20·0517
ξ Hydra	11 27 59·0	19·857	20·0523
λ Centauri	11 31 4·5	19·900	20·0595
υ Leonis	11 31 43·5	19·901	20·0534
β Leonis	11 48 51·4	20·004	20·0537
β Virginis	11 45 22·9	20·012	20·0528
B.A.C. 4007	11 46 2·7	20·016	20·0532
γ Ursæ Majoris	11 48 28·0	20·029	20·0544
π Virginis	11 55 38·7	20·049	20·0526
o Virginis	12 0 0·8	20·052	20·0520
δ Centauri	12 3 4·3	20·051	20·0528
ϵ Corvi	12 4 52·6	20·048	20·0525
δ Crucis	12 9 43·7	20·035	20·0531
δ Ursæ Majoris	12 10 22·7	20·032	20·0526
7 Corvi	12 10 33·6	20·031	20·0523
β Chamæleontis	12 12 21·6	20·030	20·0592
B.A.C. 4165	12 14 22·9	20·013	20·0525
η Virginis	12 14 41·2	20·011	20·0522
α^1 Crucis	12 20 55·3	19·970	20·0535
δ^2 Corvi	12 24 35·1	19·938	20·0533
γ Crucis	12 25 30·4	19·928	20·0521
β Corvi	12 29 1·6	19·892	20·0526
α Muscæ	12 31 5·9	19·870	20·0543
γ Centauri	12 35 53·4	19·807	20·0524
γ^1 Virginis	12 36 29·3	19·798	20·0516
ρ Virginis	12 36 43·3	19·796	20·0529
β Muscæ	12 40 1·3	19·750	20·0550
β Crucis	12 41 45·5	19·720	20·0519
35 Virginis	12 42 39·7	19·705	20·0514
31 Comæ	12 46 43·8	19·637	20·0524
ϵ Ursæ Majoris	12 49 32·5	19·586	20·0527
δ Virginis	12 50 27·9	19·568	20·0522
α Canum Venat	12 51 15·4	19·553	20·0524
ϵ Virginis	12 57 5·9	19·432	20·0511
Mean of the above seventy-three stars			20·0529

SECTION IV

ANNUAL ANGLE, DURATION OF CYCLE, AND ZERO YEAR

Having in the foregoing sections briefly explained the manner in which Drayson's primary data were ascertained, viz. the radius of second rotation 29° 25′ 47″, the distance of the centre of second rotation from the pole of the ecliptic 6°, and the annual motion of the pole 20″·0529, I will now proceed to deal with Drayson's secondary data which depend on and are deduced from the primary data, viz. the annual angle at the centre of rotation, the duration of the cycle, and the zero year, *i.e.* the year in which the pole of the ecliptic and the centre of rotation are aligned, and in which therefore the obliquity of the ecliptic will be at its minimum.

First dealing with the annual angle, viz. the angle PCP' in the accompanying diagram, we have annual angle

$$=\frac{\text{Annual motion}}{\text{sine } CP}$$

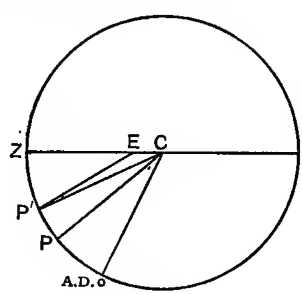
or $$\frac{20''\cdot 0529}{\text{sine } 29°\ 25'\ 47''}$$

$$\begin{array}{r} 1\cdot 3021772 \\ 9\cdot 6913952 \\ \hline \end{array}$$

Log $PCP' = 1\cdot 6107820$

Whence annual angle

$= 40''\cdot 81143$



Duration of Cycle

If the annual angle at the centre of second rotation be accepted as 40″·81143 as above stated, it follows that one

whole period of rotation is thereby determinable, and will be

$$\frac{360^\circ}{\text{annual angle}} \text{ or } \frac{1296000''}{40''{\cdot}81143}$$

Whence the duration of the cycle=31,755·814, say about 31,756 years.

The mean of my six reversed calculations to find Drayson's data made the duration of the cycle 31,777 years, but those calculations have no pretence to precise accuracy (see Section VIII.)

The Zero Year

To find the zero year, *i.e.* the year of minimum obliquity of the ecliptic, is a matter of simple geometry, if Drayson's system and his before-mentioned data be accepted.

In the foregoing figure, let C be the centre of second rotation, E the pole of the ecliptic, P the pole of the earth on any given year, and let Z represent the position of the pole in the zero year, *i.e.* when aligned with E and C. Also let O be the position of the pole of the earth at the beginning of the Christian era.

On reference to the diagram it will be manifest that the number of years from P to Z must depend on the angle $PCZ=PCE$. For example, let it be required to find the zero year from Drayson's data, and from the obliquity recorded in the Nautical Almanac of 1898.

In the triangle CPE we have $CP=29^\circ\ 25'\ 47''$, $CE=6^\circ\ 0'\ 0''$, and $EP=23^\circ\ 27'\ 8''{\cdot}98$ to find the angle C.

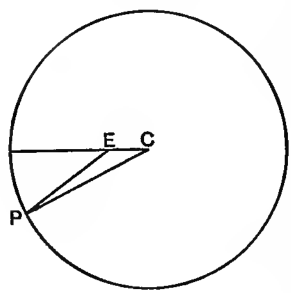
23 27 9		
6 0 0 cosec		$\frac{C}{2}=2^\circ\ 14'\ 56''$
29 25 47 cosec	0·9807654	
58 52 56	0·3086041	
29 26 28 sine	9·6915489	$C=4^\circ\ 29'\ 52''$
23 27 9	9·0184124	
5 59 19 sine	19·9993308	$=269'\ \ 52''$
	9·9996654	
	Log cosine $\frac{C}{2}$	$=16192''$

$$\text{Whence zero year} = 1898 + \frac{\text{Angle } PCZ}{\text{annual angle}}$$
$$= 1898 + \frac{16192''}{40''{\cdot}81143}$$
$$= 1898 + 396{\cdot}752$$
$$= \text{A.D.} \quad 2294{\cdot}75$$

SECTION V

THE OBLIQUITY OF THE ECLIPTIC

To find the obliquity for any given year we have in the accompanying figure the two sides CP and CE respectively 29° 25′ 47″ and 6° 0′ 0″, and the included angle PCE to find the third side EP, the obliquity.



For example, let it be required to find the obliquity in 1900.

First find the angle PCE, and transposing the expression to find the zero year (Section IV.) we have angle PCE

$$=(\text{zero year}-\text{year A.D.})\times\text{annual angle}$$
$$=(2294{\cdot}75-1900)\times 40''{\cdot}81143$$
$$=16{,}110''{\cdot}283=4^\circ\ 28'\ 30''{\cdot}283$$

With PCE thus found we have two sides and the included angle to find the third side EP $\tan\phi=\tan CE.\ \cos C$ and

$$\cos EP=\frac{\cos CE\cdot\cos(CP-\phi)}{\cos\phi}$$

	9·0216202		9·9976143
	9·9986740		9·9625693
	9·0202942		19·9601836
ϕ	5°58′54″·63		9·9976288
CP	29 25 47	Log EP	9·9625548
$(CP-\phi)$	23 26 52 ·37		

Whence obliquity in 1900=23° 27′ 8″·3.

In the above case, as in others, I feel that some apology is due to such mathematicians as may honour me by reading this work for having inserted the details of simple trigonometrical formulæ, which to them are matters as familiar as A, B, C. My excuse is that I am writing also for the young, whom I hope to entice into a study of the subject.

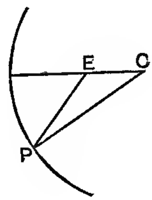
THE ANGLES *PCE* AND *CPE*

As the angle *PCE* is required in all calculations for finding the obliquity, and as the angle *CPE* will play an important part when dealing with sidereal time and right ascension, a table of these two angles for the beginning of each century is appended.

In the triangle *CEP* with the two sides *CP* and *CE*, known as constants, and the angle *C* found for any year as described in this section, it will be evident that the angle *CPE* for the same year may be found.

I also append to this section a diagram showing the obliquity curve on Drayson's system for the first 2500 years of the Christian era, together with the amount of obliquity and of its corresponding precession of the equinoxes for the beginning of each century.

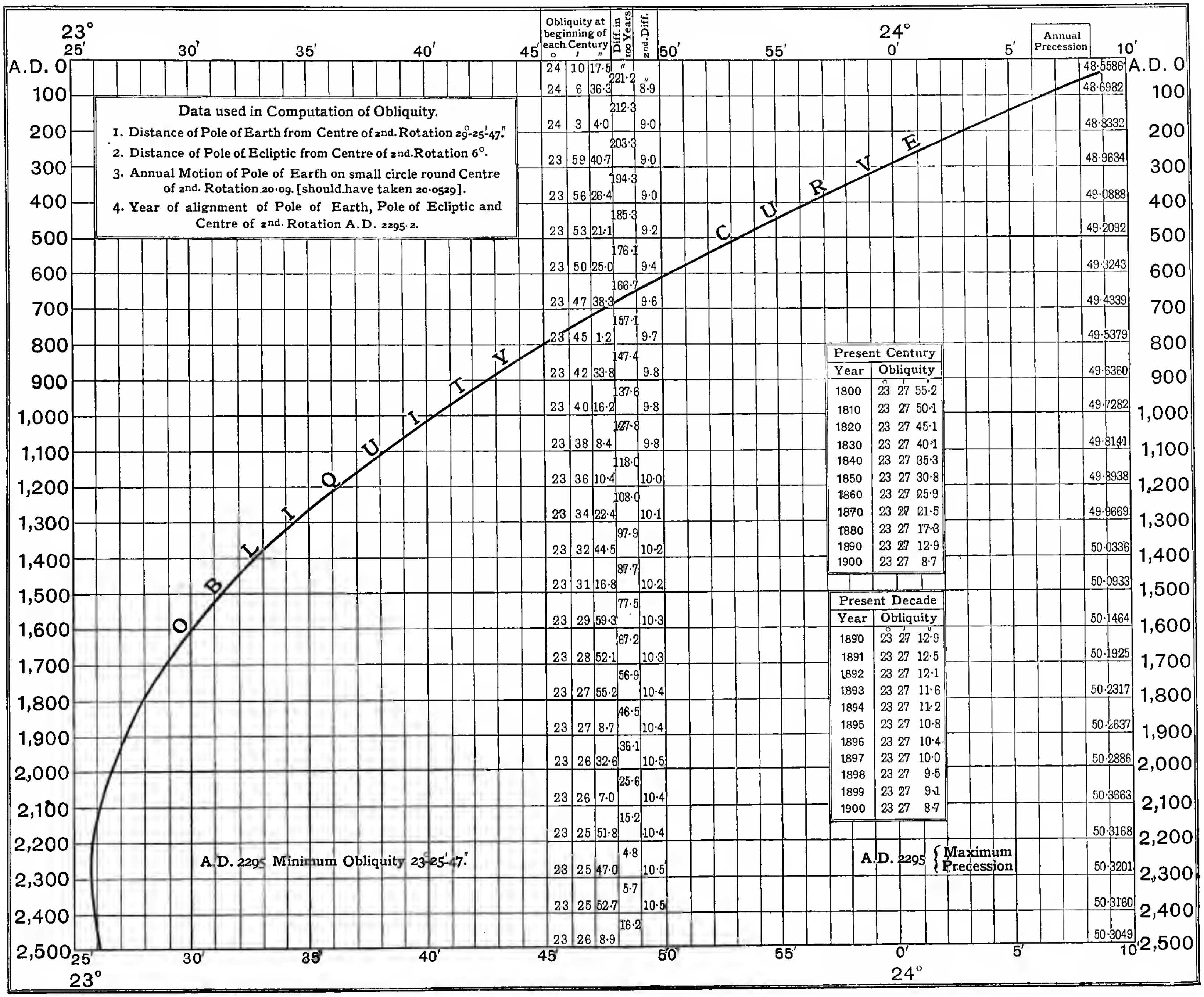
The Angles *PCE* and *CPE*



Year A.D.	*PCE*	*CPE*
0 . . .	26° 0′ 52″	6° 25′ 45″·46
100 . . .	24 52 50 ·857	6 10 52 ·07
200 . . .	23 44 49 ·714	5 55 44 ·11
300 . . .	22 36 48 ·571	5 40 21 ·90
400 . . .	21 28 47 ·428	5 24 46 ·25
500 . . .	20 20 46 ·285	5 8 57 ·45
600 . . .	19 12 45 ·142	4 52 56 ·16
700 . . .	18 4 43 ·999	4 36 42 ·93
800 . . .	16 56 42 ·856	4 20 18 ·36
900 . . .	15 48 41 ·713	4 3 43 ·08
1000 . . .	14 40 40 ·570	3 46 57 ·72
1100 . . .	13 32 39 ·427	3 30 2 ·91
1200 . . .	12 24 38 ·284	3 12 59 ·37
1300 . . .	11 16 37 ·141	2 55 47 ·65
1400 . . .	10 8 35 ·998	2 38 28 ·57
1500 . . .	9 0 34 ·855	2 21 2 ·80
1600 . . .	7 52 33 ·712	2 3 31 ·06
1700 . . .	6 44 32 ·569	1 45 54 ·05
1800 . . .	5 36 31 ·426	1 28 12 ·55
1900 . . .	4 28 30 ·283	1 10 27 ·28
2000 . . .	3 20 29 ·140	0 52 38 ·99
2100 . . .	2 12 27 ·997	0 34 48 ·45
2200 . . .	1 4 26 ·854	0 16 56 ·43
2300 . . .	0 3 34 ·289	0 0 56 ·33
2400 . . .	1 11 35 ·432	0 18 49 ·05
2500 . . .	2 19 36 ·575	0 36 40 ·95
2600 . . .	3 27 37 ·718	0 54 31 ·29
2700 . . .	4 35 38 ·861	1 12 19 ·29

MEAN OBLIQUITY OF THE ECLIPTIC ON JANUARY 1st.

Calculated for the first 25 Centuries of the Christian Era on General Drayson's System of the 2nd. Rotation of the Pole.



Data used in Computation of Obliquity.

1. Distance of Pole of Earth from Centre of 2nd. Rotation 29° 25′ 47″.
2. Distance of Pole of Ecliptic from Centre of 2nd. Rotation 6°.
3. Annual Motion of Pole of Earth on small circle round Centre of 2nd. Rotation 20·09. [should have taken 20·0529].
4. Year of alignment of Pole of Earth, Pole of Ecliptic and Centre of 2nd. Rotation A.D. 2295·2.

A.D.	Obliquity at beginning of each Century °	′	″	Diff. in 100 Years ″	2nd. Diff. ″	Annual Precession
0	24	10	17·5			48·5586
100	24	6	36·3	221·2	8·9	48·6982
200	24	3	4·0	212·3	9·0	48·8332
300	23	59	40·7	203·3	9·0	48·9634
400	23	56	26·4	194·3	9·0	49·0888
500	23	53	21·1	185·3	9·2	49·2092
600	23	50	25·0	176·1	9·4	49·3243
700	23	47	38·3	166·7	9·6	49·4339
800	23	45	1·2	157·1	9·7	49·5379
900	23	42	33·8	147·4	9·8	49·6360
1,000	23	40	16·2	137·6	9·8	49·7282
1,100	23	38	8·4	127·8	9·8	49·8141
1,200	23	36	10·4	118·0	10·0	49·8938
1,300	23	34	22·4	108·0	10·1	49·9669
1,400	23	32	44·5	97·9	10·2	50·0336
1,500	23	31	16·8	87·7	10·2	50·0933
1,600	23	29	59·3	77·5	10·3	50·1464
1,700	23	28	52·1	67·2	10·3	50·1925
1,800	23	27	55·2	56·9	10·4	50·2317
1,900	23	27	8·7	46·5	10·4	50·2637
2,000	23	26	32·6	36·1	10·5	50·2886
2,100	23	26	7·0	25·6	10·4	50·3663
2,200	23	25	51·8	15·2	10·4	50·3168
2,300	23	25	47·0	4·8	10·5	50·3201
2,400	23	25	52·7	5·7	10·5	50·3160
2,500	23	26	8·9	16·2		50·3049

Present Century

Year	Obliquity ° ′ ″
1800	23 27 55·2
1810	23 27 50·1
1820	23 27 45·1
1830	23 27 40·1
1840	23 27 35·3
1850	23 27 30·8
1860	23 27 25·9
1870	23 27 21·5
1880	23 27 17·3
1890	23 27 12·9
1900	23 27 8·7

Present Decade

Year	Obliquity ° ′ ″
1890	23 27 12·9
1891	23 27 12·5
1892	23 27 12·1
1893	23 27 11·6
1894	23 27 11·2
1895	23 27 10·8
1896	23 27 10·4
1897	23 27 10·0
1898	23 27 9·5
1899	23 27 9·1
1900	23 27 8·7

SECTION VI

THE PRECESSION OF THE EQUINOXES

THE yearly amount of precession of the equinoxes seems to have been somewhat uncertain. Herschel appears to have thought it a constant of $50''\cdot10$. But more modern orthodoxy has shown it to be a variable quantity increasing slightly as the obliquity decreases, and *vice versâ*. According to Drayson's system the precession at present is an increasing quantity with a diminishing rate of increase, and will attain its maximum amount of about $50''\cdot32$ in about A.D. 2295, after which date it will slowly decrease with a slowly increasing rate of decrease.

I will now endeavour to explain my method of ascertaining the precession in accordance with Drayson's system.

The annual angle of second rotation $40''\cdot81143=2^{s}\cdot721$, which yearly amount the earth has rotated in opposition (nearly) to the daily rotation (Drayson).

Over what arc, then, of the ecliptic will the earth traverse during $2^{s}\cdot721$? Taking the precession roughly at $50''\cdot2$ the earth travels $360°-50''\cdot2$ during 365 d. 6 h. 9 m. 9·6 s. (=365 d.·25636).

Then as $360°-50''\cdot2=1295949''\cdot8$ we have

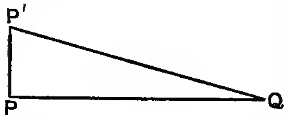
$$\frac{1295949\cdot8}{365\cdot25636}=3548''\cdot0565$$

whence the ecliptic travels each day $3548''\cdot0565=59'8''\cdot0565$.

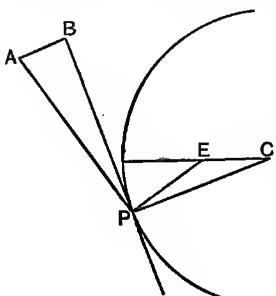
If the earth travels $59'\ 8''\cdot0565$ during twenty-four hours, what arc—call it X—will it travel over during $2''\cdot721$? (24 h.=86400s.)

$$\frac{86400}{2\cdot721}=\frac{3548''\cdot0565}{X}$$

whence in $2^s \cdot 721$ the earth travels $0'' \cdot 11174$, which amount may be considered a constant for 2000 years or more, and should be subtracted from the precession found by the precession triangle in which PP' is the annual motion of the pole, the angle Q the obliquity, and $P'Q$ the approximate precession.



We should thus have precession$=\dfrac{PP'}{\sin Q}-0''\cdot 11174$. This might be correct if the pole travelled in a circle round E, the pole of the ecliptic, as a centre, but as by Drayson's system the annual revolution is round C as a centre, the annual motion must be reduced to the amount it would be if it were direct towards the first point of Aries. To exemplify this: From P in the accompanying figure draw PA at right angles to EP, and therefore towards the first point of Aries draw PB at right angles to CP. Also draw AB at right angles to AP. Let BP represent an exaggeration of the annual motion. Then AP will be the reduced annual motion required for computing the precession.



As APE and BPC are right angles, and BPE is common to both, the angle $APB=CPE$, which latter can be found for any year as shown in Section v.

Thus in the triangle ABP right-angled at A we have $PA=PB\cdot\cos P$. Whence

$$\text{Precession}=\frac{PA}{\text{sin obliquity}}-0''\cdot 11174$$

$$=\frac{\text{Annual motion}\times\text{cosine } CPE}{\text{sin obliquity}}-0''\cdot 11174.$$

For example: let it be required to find the precession in 1900 and in 1910 by the above formula, observing that the annual motion $20''\cdot 0529$ and $-0\cdot 11174$ are constants.

1900.		1910.	
Given N.A. obliquity	23°27′ 8″·03	Given N.A. obliquity	23°27′ 3″·58
Angle CPE . .	1 10 27 ·28	Angle CPE . .	1 9 30
(as found in Section v.)		(as found in Section v.)	
Log annual motion .	1·3021772	Log annual motion .	1·3021772
Log cos P . . .	9·9999088	Log cos P . . .	9·9999112
	11·3020860		11·3020884
Log sin obliquity .	9·5998660	Log sin obliquity .	9·5998444
	1·7022200		1·7022440
	50″·37556		50″·37836
	− 0·11174		− 0·11174
Precession . .	50·26382	Precession . .	50·26662
Do. by Naut. Almanac	50·2639	Do. by Naut. Almanac	50·25865
Difference . .	0·00008	Difference . .	0·00797

A similar calculation for the year 1898 with the Nautical Almanac obliquity 23° 27′ 8″·98 and the angle P (computed as shown in Section v.) 1° 10′ 48″·6 gives the following result:—

Precession by this method	50″·26318
Do. by Nautical Almanac	50 ·2633
Difference	0 ·00012

Assuming the Nautical Almanac obliquities and precessions to be correct, the above results respectively show only about $\frac{8}{100000}$, $\frac{8}{1000}$, and $\frac{1}{100000}$ of a second of arc different from the Royal Observatory figures given in the Nautical Almanac; this in my opinion is an additional test, and goes far to prove the accuracy of my method of finding the precession for any year, past, present, or future, under Drayson's system.

To this section is appended a table which I calculated some ten years ago to show the obliquity and precession for the commencement of each century, and to A.D. 2700; also a table of yearly diminution of obliquity from 1851 to 1950 under Drayson's system. These tables will perhaps lead to more accurate investigation, and may be of interest even to those who do not admit the soundness of Drayson's system.

The data from which the tables are computed are the radius CP 29° 25′ 47″, the annual motion of the pole 20″·0529, CE the distance between the centre of second rotation and the pole of the ecliptic 6°, and the angle PCE, as found for each year from the above-mentioned data.

In the foregoing examples of a method of finding the precession, and also in the table of precessions which follows, the direction of the first point of Aries has been assumed to be at right angles to the pole of the ecliptic as generally accepted, but as I understand Drayson's system the first point of Aries should be considered to be at right angles to CP, the line between the pole of the earth and the pole of second rotation, in which case the precessions before found would be respectively for 1898 50″·27383, for 1900 50″·27441, and for 1910 50″·27692.

These figures, in my opinion, are likely to be more correct than those which agree with the amounts given in the Nautical Almanac. The difference between the result of the two systems is about 0″·0106 in the year 1900.

If it be accepted that the first point of Aries is at right angles to the direction of the centre of second rotation, the item cos CPE may be eliminated from the formula for finding the precession, and the expression will then be

$$\text{Precession} = \frac{\text{Annual motion}}{\text{sine obliquity}} - 0''\cdot 11174.$$

The precessions, however, given in the following tables are calculated on what I believe to be the orthodox assumption that the first point of Aries is 90° from the pole of the ecliptic.

Obliquity of the Ecliptic and Precession of the Equinoxes at the Beginning of each Century

A.D.	Obliquity.	Diff. in 100 years.	2nd Diff.	Precession.	Diff. in 100 yrs.	2nd Diff.
0	24° 10′ 7″·1			48″·5586		
		220″·5			·1396	
100	24 6 26·6		8″·9	48·6982		·0046
		211·6			·1350	
200	24 2 55·0		9·1	48·8332		·0048
		202·5			·1302	
300	23 59 32·5		8·9	48·9634		·0048
		193·6			·1254	
400	23 56 18·9		8·9	49·0888		·0050
		184·7			·1204	
500	23 53 14·2		9·4	49·2092		·0053
		175·3			·1151	
600	23 50 18·9		9·3	49·3243		·0055
		166·0			·1096	
700	23 47 32·9		9·5	49·4339		·0056
		156·5			·1040	
800	23 44 56·4		9·7	49·5379		·0059
		146·8			·0981	
900	23 42 29·6		9·5	49·6360		·0059
		137·3			·0922	
1000	23 40 12·3		9·9	49·7282		·0063
		127·4			·0859	
1100	23 38 4·9		9·9	49·8141		·0062
		117·5			·0797	
1200	23 36 7·4		10·1	49·8938		·0066
		107·4			·0731	
1300	23 34 20·0		9·8	49·9669		·0064
		97·6			·0667	
1400	23 32 42·4		10·3	50·0336		·0070
		87·3			·0597	
1500	23 31 15·1		10·3	50·0933		·0065
		77·0			·0531	
1600	23 29 58·1		10·1	50·1464		·0070
		66·9			·0461	
1700	23 28 51·2		10·1	50·1925		·0069
		56·8			·0392	
1800	23 27 54·4		10·7	50·2317		·0072
		46·1			·0320	
1900	23 27 8·3		10·1	50·2637		·0071
		36·0			·0249	
2000	23 26 32·3		10·6	50·2886		·0072
		25·4			·0177	
2100	23 26 6·9		10·2	50·3063		·0072
		15·2			·0105	
2200	23 25 51·7		10·5	50·3168		·0072
		4·7			·0033	

Obliquity of the Ecliptic and Precession of the Equinoxes at the Beginning of each Century—*contd.*

A.D.	Obliquity.	Diff. in 100 years.	2nd Diff.	Precession.	Diff. in 100 yrs.	2nd Diff.
2300	23° 25′ 47″·0		10″·6	50″·3201		·0074
		5″·9			·0041	
2400	23 25 52 ·9		10 ·1	50 ·3160		·0070
		16 ·0			·0111	
2500	23 26 8 ·9		10 ·8	50 ·3049		·0075
		26 ·8			·0186	
2600	23 26 35 ·7		10 ·2	50 ·2863		·0071
		37 ·0			·0257	
2700	23 27 12 ·7			50 ·2606		·00

In the above table some irregularity will be observed in the columns headed Second Difference, which, of course, should not be; the reason for such irregularity in calculations will be obvious.

Annual Difference of Obliquity from 1851 to 1950

Year A.D.	Annual Diff.	Year A.D.	Annual Diff.	Year A.D.	Annual Diff.	Year A.D.	Annual Diff.
1851	0″·458	1876	0″·435	1901	0″·411	1926	0″·385
1852	·457	1877	·434	1902	·410	1927	·384
1853	·456	1878	·433	1903	·409	1928	·383
1854	·456	1879	·432	1904	·408	1929	·382
1855	·455	1880	·431	1905	·407	1930	·380
1856	·454	1881	·430	1906	·406	1931	·379
1857	·453	1882	·429	1907	·405	1932	·378
1858	·452	1883	·428	1908	·404	1933	·377
1859	·451	1884	·427	1909	·403	1934	·376
1860	·450	1885	·426	1910	·402	1935	·375
1861	·449	1886	·425	1911	·401	1936	·374
1862	·448	1887	·424	1912	·400	1937	·373
1863	·447	1888	·423	1913	·399	1938	·372
1864	·447	1889	·422	1914	·398	1939	·371
1865	·446	1890	·421	1915	·397	1940	·369
1866	·445	1891	·421	1916	·395	1941	·368
1867	·444	1892	·420	1917	·394	1942	·367
1868	·443	1893	·419	1918	·393	1943	·366
1869	·442	1894	·418	1919	·392	1944	·365
1870	·441	1895	·417	1920	·391	1945	·364
1871	·440	1896	·416	1921	·390	1946	·363
1872	·439	1897	·415	1922	·389	1947	·362
1873	·438	1898	·414	1923	·388	1948	·361
1874	·437	1899	·413	1924	·387	1949	·360
1875	·436	1900	·412	1925	·386	1950	·359

SECTION VII

STANDARD OF TIME AND RIGHT ASCENSION

Before considering the question of time, I may perhaps, with the garrulousness of age, take permission to make a short dissertation. Some sixty-four years ago, when frozen up at Fort Vancouver, about a hundred miles up the Columbia River, and with plenty of time for thought, I argued with my young brother officers, now all dead, that the confusion of time with longitude was a mistake, and that, as a lapse of time is measured by the number of beats of a pendulum of a certain length in a certain latitude, time must go on whether or no the observer changes his longitude on the earth, and that consequently there should be one and the same time at all places. An hour of time means a lapse of 3600″, and that time will have elapsed whether the observer has moved or is stationary. I am much interested to observe in the Press that it is proposed to adopt the same time as at Greenwich over a large part of the Continent—a change which would greatly add to the convenience of the travelling public, and which gives me hope that in the distant future the day will come when a watch pointing to twelve hours will represent twelve o'clock all over the civilised world.

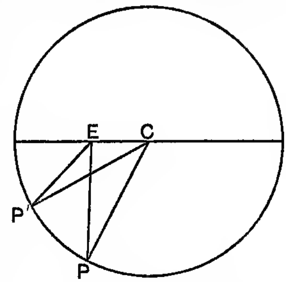
Although not bearing directly on the subject of time, it may not be out of place to remind my young readers with regard to cardinal points that there is no east and there is no west in the solar system or in the universe. The terms east and west are merely planetary, and refer only to the direction in which an observer on a planet can note the apparent rising and setting of the heavenly bodies. There is a north and there is a south, so called from the direction

of the respective poles of the earth produced to the heavenly sphere. But just as an observer standing at one of the poles would have no east or west, so in the heavenly sphere such points are non-existent.

Coming to the question of sidereal time, the ecliptic in a terrestrial globe is usually shown to cross the equator in the meridian of Greenwich; but this has no particular signification, as the ecliptic must be shown to cross the equator somewhere. So far as I have learnt, the zero meridian for right ascension is that meridian which passes through a point on the heavenly sphere which would be indicated by a straight line from the centre of the earth through the centre of the sun at the instant of the sun's polar distance being 90° at the vernal equinox. This point on the heavenly sphere is called the first point of Aries, and was so termed because it was situated some centuries ago at the beginning of the sign of the zodiac called Aries. The first point of Aries is now, I believe, about 20° or more from that position, and has an annual and varying motion. The above description of the zero point of annual sidereal time may or may not be correct, as I have no pretence to be an authority on the subject.

According to Drayson's system the axis of the earth changes its inclination about 20″·0529 in each year on a small circle distant 29° 25′ 47″ from *C*, the centre of second rotation. It can be shown by a diagram that if at the vernal equinox in any year the centres of the earth and sun and a fixed point in the heavens, such as a distant star, were aligned, at the next year's vernal equinox the same distant star would not be aligned. This is because the change of about 20″·0529 in the direction of the earth's axis would by that movement alter the condition that the sun's polar distance shall be 90° at the vernal equinox. The practical result of the alteration in the inclination of the earth's axis is that the condition of 90° polar distance will be fulfilled, and therefore the vernal equinox occur a little before the alignment of the distant star. This difference in the position of the first point of Aries, termed precession of the equinoxes, is a quantity which varies

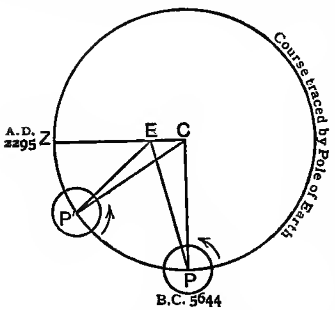
with the obliquity of the ecliptic, and according to the amount of the angle *CPE* in the accompanying diagram, as described in Section VI., *C*, *E* and *P* being respectively the centres of second rotation, of the pole of the ecliptic, and the pole of the earth.



With regard to the foregoing definition of the zero of sidereal time, I have no remark to make, as I am not practically acquainted with the manner in which our distinguished astronomers, with their very accurate instruments, set their imaginary sidereal clock at *O* for the beginning of each sidereal year. Nor does the accurate setting of the clock concern the matter with which I am dealing, which is the rate of the clock, not its error. But seeing the addition of more than 3^{m} of imaginary time in the year 1834, it is reasonable to think that there had been an error, and that another error may be accumulating by means of a slightly incorrect rate.

It is fair to assume that the Astronomer Royal of the day in 1834 knew his business, and would not have made so important a change of sidereal time as an addition of $3^{m}\ 3^{s}{\cdot}68$ without sound reason for so doing. Be it also observed that the addition was not a mere rough amount of minutes, but was stated with an accuracy purporting to be to the hundredth part of a second. Assuming therefore that the time of the vernal equinox was correctly ascertained in 1834, it is not without interest to note that the determination of Mr. Stone —then Radcliffe Observer at Oxford—that an error of time in 1892 had amounted to $41^{s}{\cdot}51$ agrees within a small fraction of a second with the error $41^{s}{\cdot}283$ ascertained by Drayson's system, viz. the accumulation of about $0^{s}{\cdot}71$ per annum since 1834. This similitude may possibly be a coincidence, or Mr. Stone may have been in error, but otherwise it appears to be in some measure an additional evidence of Drayson's system of second rotation. According to Drayson this slight annual error in sidereal time is in consequence

of the assumption that the pole of the earth travels round the pole of the ecliptic in a period of some 25,000 years, instead of, as he affirms, round the centre of rotation in some 30,000 years, and says that for a correct standard of time it should be measured with C as a centre. If in the diagram P and P' be the positions of the pole of the earth in two consecutive years, the annual error of rate will be the difference between the angles CPE and $CP'E$, which in 1910 amounts to $10''{\cdot}66$, or in time $0^{s}{\cdot}71143$.



On the subject of a standard measure of time I write with some diffidence, and prefer where practicable to quote Drayson's own words. In a letter to me dated 3rd January 1894, Drayson gives me the above diagram, referring to the date about 5644 B.C., in which P is the position of the pole at date 5644 B.C., C the pole of the second rotation, $PC=29^\circ\ 25'\ 47''$, E true position of pole of the ecliptic, $CE=6^\circ$, and $ECP=90^\circ$.

'When the pole of the earth is at P, a daily rotation will cause C to transit before E by an interval of time measured by the angle EPC.

'When the pole has been carried to P', a daily rotation will cause C to transit before E by an interval of time measured by the angle $EP'C$, and when the pole reaches Z A.D. 2295 C and E will transit simultaneously.

'The successive transits of C, the centre of the circle, give a uniform measure or standard of time. The successive transits of E, therefore, give a variable measure of time, which also has a variable rate depending on the variation in the angle EPC as the pole is carried round from 5644 B.C. to A.D. 2295.

'The intersection of the equator and ecliptic giving the equinoctial point (first of Aries) is the point from which right ascensions are counted, and as the pole is not moving at

right angles to the arc joining it with the pole of the ecliptic, the successive transits of the pole of the ecliptic do not correspond with the successive transits of C.

‘The variation in the angle $EP'C$ from year to year and from century to century becomes therefore a very important item, because the successive transits of C give a uniform standard of time; hence the successive transits of E give less than a uniform standard of time, and the measure of right ascension is affected thereby.

‘The change in the angle $EP'C$ from century to century can be easily calculated as follows :—$CE=6°$, $CP'=29° \ 25' \ 47''$, and the angle at $C=(2295{\cdot}2-\text{date})\times 40''{\cdot}9$. Hence with two sides and the included angle the angle $EP'C$ can be found.

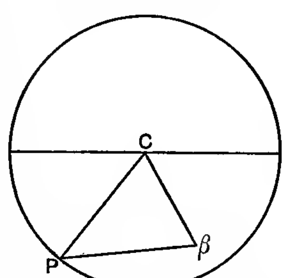
‘Thus for 1st January 1887 this angle $=1° \ 12' \ 58''$
,, ,, ,, 1787 ,, ,, $=1 \ \ 30 \ \ 45$
‘Difference for a hundred years, 1787 to 1887 $=0 \ \ 17 \ \ 47$
that is, 1067″ for that century, or 10″·67 per year. The rate will not be quite uniform, but near enough to uniformity for practical use.

‘Now for the application of this fact. A date must be fixed on as a zero, and I fixed on 1st January 1887, the Jubilee year, therefore easily remembered. The correction of 10″·67 for the erroneous standard of time will be minus for dates previous to 1887 and plus for dates after 1887.

Example I

‘Let it be required to find the right ascension of β Ursæ Minoris for the 1st January 1818.

‘Having calculated $C\beta$ as before shown, we have $PC=29° \ 25' \ 47''$, $P\beta$ the polar distance $15° \ 6' \ 2''{\cdot}4$ as per Nautical Almanac of 1818, and $C\beta$ $21° \ 50' \ 12''$. Hence in the accompanying diagram we have PC, $P\beta$, and $C\beta$ to find the angle P, which will be found to be $46° \ 57' \ 35''{\cdot}2$, or in time 3 h. 7 m. 50·4 s.



As this star is in the third quarter of right ascension the

angle P must be subtracted from 18 hours, which gives 14 h. 52 m. 9·6 s. as the approximate right ascension.

'Between 1818 and 1887 are 69 years to be corrected for erroneous standard of time at 10″·67 per year.

$$10''\cdot67 \times 69 = 12'\ 16'' = 49^{s}\cdot1 \text{ in time.}$$

	h.	m.	s.	
	14	52	9·6	
			−49·1	
By calculation .	14	51	20·5	
Recorded N.A. .	14	51	20·69	
	0	0	0·19	difference in 69 years.

EXAMPLE II

'To find the right ascension of β Dràconis on 1st January 1895.

'Given $CP=29°\ 25'\ 47''$, $C\beta=9°\ 17'\ 38''$, and $P\beta$ the polar distance in 1895=37° 37′ 15″. (See diagram in Example I.)

'With the three sides find the angle $CP\beta$, which will be found to be 8° 0′ 32″.

8° 0′ 32″=0 h. 32 m. 2·1 s.

Take from . .	18	0	0
	17	27	57·9

Between 1887 and 1895=8 years.

$$10''\cdot67 \times 8 \text{ years} = 1'\ 25''\cdot36 = 5^{s}\cdot69 \text{ in time.}$$

Brought down .	17 h.	27 m.	57·9 s.	
Correction . .			+5·69	
	17	28	3·59	R.A. by calculation.
	17	28	3·55	R.A. by N.A.
	0	0	0·04	difference.'

About the year 1900 I received from General Drayson the following further explanation of his system relating to a correct standard of sidereal time:—

Standard of Time and Right Ascension

'Without entering into a long and elaborate explanation of the standard of time, I may state that astronomers have assumed that they have a true standard of time by aid of a knowledge of one complete rotation of the earth on its axis.

'But, what is a complete rotation of the earth on its axis, and how can it be measured? In consequence of the second rotation of the earth, every star within the circle described by the pole will transit once oftener during an entire revolution of the equinoxes than will those stars outside this circle. Hence it follows that the only true and uniform standard of time which represents a true rotation of the earth is that point in the heavens at which the pole of second rotation is located. As the position of this point has been hitherto unknown, there exists at the present time a slight error in the supposed rotation of the earth amounting to *about* $0^s{\cdot}711$ per year.

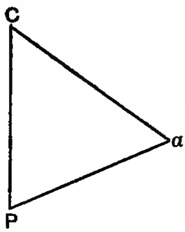
'The right ascension of stars is the term used to define the interval of time *shown by a chronometer* between the transit of a zero point in the heavens and the transit of the star.

'Any error as small as $0^s{\cdot}711$ per year might go on accumulating during several years, and might then be adjusted at all the observatories without the outside public knowing anything about it. Such was the case between the years 1833 and 1834, when $3^m\ 3^s{\cdot}68$ of purely imaginary time was inserted to balance accounts. Outsiders, unless possessing an observatory, and having the best instruments, chronometers, etc., have no means of discovering the right ascension of the stars other than accepting that which is given in the Nautical Almanac. A person may know there is an error in the standard measure of time, and yet for calculation he *must* take the data given in the Nautical Almanac in order to work out details. For example—

'I selected the date 1887 as a zero, and in the Nautical Almanac, 1887, I found that the star α Draconis had

R.A. 14 h. 1 m. 19·743 s. Decn. N. $64° 54' 57''{\cdot}84$.

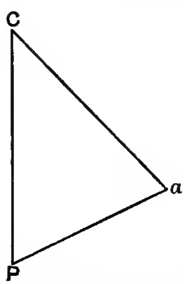
'I knew that $PC = 29° 25' 47''$. *From Nautical Almanac* I obtained Pa and the angle CPa, and from this data I could calculate Ca and the angle PCa. And hence, as I have proved, I can calculate the N.P.D. and assigned R.A. of this and other stars for a hundred years and more.



'But the interval of time of transit between a and C is measured year after year by a chronometer which does not give the exact value of the earth's rotation, and hence there is an accumulating error which for any other date, say 1900, will give a slightly different value for the angle PCa and the side Ca. Yet by making 1900 the zero the same accurate results can be obtained. Example—

Nautical Almanac, 1900, a Draconis.
R.A. 14 h. 1 m. 40·88 s. N. Decn. 64° 51′ 13″·35.

'*From this Nautical Almanac data* I obtain the following:—



$$\left.\begin{aligned} \angle CPa &= 59° \ 34' \ 46''\cdot 8 \\ Pa &= 25 \quad 8 \quad 46\cdot 65 \end{aligned}\right\} \text{Nautical Almanac.}$$
$$CP = 29 \quad 25 \quad 47.$$

'*From this Nautical Almanac data* I find by calculation that $Ca = 26° \ 36' \ 9''\cdot 1$ and $\angle C = 54° \ 54' \ 54''$ for 1900·0.

'These two values differ slightly from the values found for the zero 1887, because the standard measure of time between 1887 and 1900 used by astronomers is in error.

'I now have my constants for 1900·0, viz. $PC = 29° \ 25' \ 47''$, $Ca = 26° \ 36' \ 9''\cdot 1$, and $\angle C = 54° \ 54' \ 54''$. For a Draconis (see p. 54, *Untrodden Ground*) I have taken the angle C to vary $40''\cdot 9$ per year, and I now calculate the N.P.D. and R.A. of a Draconis for 1755. *From zero* 1900·0.

'Between 1755 and 1900 there are one hundred and forty-five years. $145 \times 40\cdot''9 = 1° \ 38' \ 50''\cdot 5$. Angle C in 1900 $=$ $54° \ 54' \ 54''$, angle C in 1755 $\therefore = 53° \ 16' \ 3''\cdot 5$.

'From above calculate N.P.D. a Draconis 1755:—

$L \cos 53°16'3''.5 = 9.7767577$	$+29°25'47''$	$\cos 26°36'9''.1 = 9.9514028$
$L \tan 26\ 36\ 9\ .1 = 9.6996798$	$-16\ 40\ 28$	
$16°40'28'' \tan = 9.4764375$	$12\ 45\ 19$	$\cos \qquad = 9.9891480$
		19.9405508
		$-\cos 16°40'28'' \quad 9.9813431$

N.P.D. 1755 $= 24°26'47''.2 = \cos 9.9592077$

1755 by Bradley. $24\ 26\ 47\ .4$.

For angle at P 1755. Hence Right Ascension 1755.

$\text{Sin } 53°16'\ \ 3''.5 = 9.9038698$
$\text{Sin } 26\ 36\ \ 9\ .1 = 9.6510826$
19.5549524
$-\text{Sin } 24\ 26\ 47\ .2 = 9.6168351$
$9.9381173 \sin 60°8'4'' = 4$ h. 0 m. 32·3 s.

h.	h. m. s.	h. m. s.	
18	−4 3 32·3	=13 59 27·7	145 years × 0″·711 = 1′43″·09
Deduct .	.	. 1 43·09	
		13 57 44·61	R.A. 1755 by calculation.
By Bradley	.	13 57 46·3	
Difference	.	0 0 1·69	for 145 years.

'From this calculation I think it will be made clear that there is nothing wonderful or special about A.D. 1887. It is unfortunate that by the erroneous standard of time now used I cannot, from *recorded observations of R.A.* at various dates, obtain always the same value for Ca. I therefore cannot tell *exactly*, and have no means of telling, what is the exact distance of Ca, as I am dependent on the astronomer's clock for the assigned R.A. at various dates. I should hesitate to determine the values of Ca and $\angle C$ from records previous to [illegible] was then fudged in, but how adjusted I [illegible] n even now, because if Mr. [illegible] there is an error of 41^s in time, I may be misled. What I can say is, that given the conventional R.A. and N.P.D. at any date, I can calculate these items for a hundred and forty-five years to one second, no matter whether I make 1887, 1900, or any other date my zero.

'There seems to be a slight misunderstanding as to what has been termed the correct R.A. at a given date. When I have fixed on a date, say 1887, I must take the Nautical Almanac clock at that date, and set my imaginary chronometer *to exactly the same time for that date.* Hence on the 1st January 1887 the two clocks agree. As, however, the rates of the two clocks are not the same, but have a difference of about 0″·711 per year, there would be a difference of $0^{s}\cdot711$ on 1st January 1888, of $0''\cdot711\times2$ on 1st January 1889, and so on.

'If I take 1900 as my zero, I set my imaginary chronometer to the same time as the N.A. clock, as shown by the R.A. of stars, and then work as before. It is not a question of "what is the correct R.A. at any date," because R.A. is not a finite quantity like polar distance. R.A. is measured from an imaginary first point of Aries as a zero, and by a clock which has a certain rate. Another clock which has a different rate would give a different result.

'Although at the date 2294·75 the two points E and C would transit simultaneously, it does not follow that the two clocks would agree at that date. Astronomers know nothing about the point C; they keep their chronometers going at a rate corresponding to what they assume to be a true rotation of the earth, and if they made no readjustments their chronometers at 2294·75 would show just the difference of $0^{s}\cdot711$, etc., for each year that it now shows. To assume that at 2294·75 the two chronometers would agree, and then to work back to 1755 and correct the error from 2294·75 to 1755, viz. $+6^{m}\ 24^{s}\cdot7$, and show a difference of $7^{m}\ 56^{s}\cdot8$ is not sound.

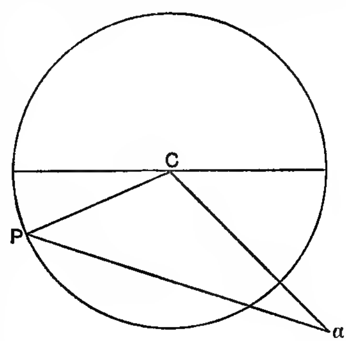
'If we had two chronometers, which we set on 1st January 1887, and chronometer A had a rate of $0^{s}\cdot711$ per year different from chronometer B, what right have we to assume that at 2294·75 the two chronometers would agree? One of my greatest difficulties and uncertainties is, whether the point C is fixed, or whether it has a slight movement in some direction. Whilst it would take a great force, or alteration of the centre of gravity of the earth, to alter the position of the poles of daily rotation *in the earth,* it would require only a

comparatively small force to alter the position of the pole of second rotation. This can be tested with a spinning top: a small force will cause the top to sway differently, but you cannot make it rotate rapidly round another axis.

'A. W. D.'

The reason for the selection of 1887 as a zero year may not at first be apparent. It appears to have been selected because it was the year for which Drayson had made hundreds of calculations, and because being the year of Queen Victoria's jubilee it can easily be remembered. Of course, neither of these reasons would of themselves be considered sufficient. But in the selection of a year Drayson had, so to speak, to set his imaginary sidereal clock at zero to correspond with the orthodox sidereal clock, whether such clock was right or wrong, his object being, not to correct any existing error in the exact time of the vernal equinox (a task only practicable by skilled astronomers at an observatory), but to establish a correct rate for the maintenance of a standard of time.

Having selected 1887 as the year in which the angle CPa in the accompanying diagram would, without correction, represent the right ascension of a, the next proceeding is to find the distance of the star a from the centre of second rotation, which can readily be done, as the two sides CP 29° 25′ 47″, Pa the polar distance, and the included angle CPa the right ascension, are known; the two latter being taken from the Nautical Almanac.

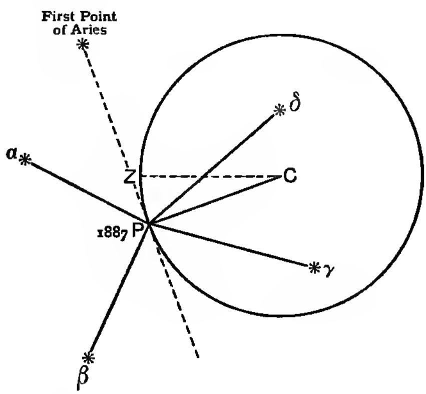


Having found Ca, or the distance from C to any other star, similarly such distances of such stars from the centre of second rotation will be constants, and available for calculation of their right ascension in any other year, provided that the angle CPa be corrected for the accumulated annual error of rate for the number of years

after or before 1887, plus or minus as before stated in this section.

The diagram which follows and its explanation will perhaps best show how the right ascension of a star is deduced from the angle *CP* star.

A table showing the distance of some stars from the centre of second rotation is appended. The calculations were made by General Drayson.



Stars' R.A. 1st January 1887, *according to Nautical Almanac standard of time.*

Naut. Alm.	R.A. of	α in	1st	quadrant	of R.A.	$=CP\alpha-6$ h.
,,	,,	β ,,	2nd	,,	,,	$=18$ h.$-CP\beta$.
,,	,,	γ ,,	3rd	,,	,,	$=18$ h.$-CP\gamma$.
,,	,,	δ ,,	4th	,,	,,	$=18$ h.$+CP\delta$.

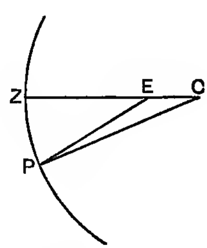
For years other than 1887, to find the Nautical Almanac R.A. the angle *CP* star must be corrected for the yearly error of time, which (for the present quarter-century) is about $0^s{\cdot}711$ per year from 1887, this correction being *plus* for years after that date, and *minus* for years previous to it.

Distance of some Stars from the Centre of Second Rotation

Mag.	Approximate. R.A.	Approximate. N.P.D.	Name of Star.		Distance from Pole of Second Rotation.		
2	0°·6	108°·8	β Ceti	Deneb Kaitos	110°	46′	5″·9
2	1 ·3	1 ·5	α Ursæ Minoris	Polaris	29	52	51
1	5 ·1	98 ·3	β Orionis	Rigel	126	54	8 ·7
1·2	7 ·6	61 ·6	β Geminorum	Pollux	88	52	53 ·5
4	8 ·9	77 ·5	α Cancri .	. . .	99	30	25
4	9 ·8	63 ·3	μ Leonis .	. . .	81	32	26
2	11 ·0	27 ·4	α Ursæ Majoris	Dubhe	44	48	33
3·4	11 ·4	19 ·8	α Draconis	. . .	37	35	41
2·3	12 ·5	112 ·6	β Corvi .	. . .	106	19	52 ·2
3·2	12 ·9	78 ·2	ε Virginis	. . .	73	0	33 ·7
1	13 ·3	100 ·4	α Virginis	Spica	89	46	33 ·3
2	13 ·7	39 ·9	η Ursæ Majoris	Benetuach	36	31	5 ·5
3·4	14 ·0	24 ·9	α Draconis	. . .	26	37	4
2·3	14 ·8	105 ·4	α Libræ	Zubenesch	85	32	36 ·4
2	14 ·9	15 ·2	β Ursæ Minoris	Kochab	21	50	12
2	15 ·2	81 ·2	β Libræ .	. . .	77	5	20 ·8
1·2	16 ·4	16 ·1	α Scorpii	Antares	89	4	17 ·1
4·5	16 ·6	7 ·7	ε Ursæ Minoris	. .	22	1	47 ·7
3·4	17 ·2	75 ·4	α^1 Herculis	Ras Algethi	46	57	32 ·7
3·2	17 ·5	37 ·6	β Draconis	. . .	9	17	38
3·4	19 ·3	87 ·2	δ Aquilæ	. . .	59	39	20
6·7	19 ·9	1 ·1	λ Ursæ Minoris	. .	28	29	2 ·7
3·4	20 ·2	103 ·0	α^2 Capricorni	Secunda Girdi	78	1	9 ·7
2·1	20 ·6	45 ·3	α Cygni	Deneb	27	55	7 ·5

Difference between Orthodox and Drayson's Time

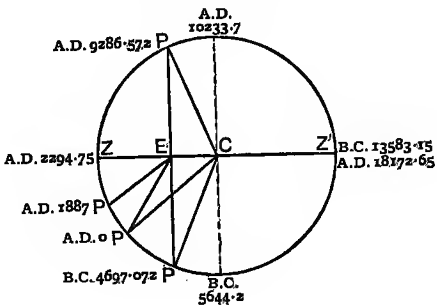
Year A.D.	Angle *CPE.*	Error in Time and R.A. per century. In Arc.	Error in Time and R.A. per century. In Time.	Annual Error.	Diff.
			secs.	secs.	secs.
1500	2° 21′ 2″·8				·0
		17′ 31″·74	70·117	0·70117	
1600	2 3 31 ·06				·00351
		17 37 ·01	70·468	0·70468	
1700	1 45 54 ·05				·00298
		17 41 ·50	70·766	0·70766	
1800	1 28 12 ·55				·00252
		17 45 ·27	71·018	0·71018	
1900	1 10 27 ·28				·00201
		17 48 ·29	71·219	0·71219	
2000	0 52 38 ·99				·00150
		17 50 ·54	71·369	0·71369	
2100	0 34 48 ·45				·00099
		17 52 ·02	71·468	0·71468	
2200	0 16 56 ·43				·00049
		16 56 ·43	67·762	0·71517	
2294·75	0 0 0				
		(In 94·75	years)	0·71520	



The Angle *PCZ* or *PCE* at the following Periods A.D.

1500 . .	9° 0′ 34″·87	2000 . .	3° 20′ 29″·17
1600 . .	7 52 33 ·74	2100 . .	2 12 28 ·02
1700 . .	6 44 32 ·59	2200 . .	1 4 26 ·88
1800 . .	5 36 31 ·45	2294·75 .	0 0 0
1900 . .	4 28 30 ·31		

The following diagram of Drayson's cycle of second rotation and accompanying table are intended to show the period



at which the angle CPE and its annual difference will respectively attain their maximum and minimum, the latter—the annual difference—being the principal factor for obtaining a standard rate of time. The diagram is based upon the following data :—

$PC=29° 25' 47''$, $CE=6°$, the annual angle at $C=40''·81143$, and the zero year of minimum obliquity A.D. 2294·75.

Principal Periods of Cycle

Year.	CEP.	ECP.	Obliquity.	CPE.	Diff. of CPE per year. In Arc.	Diff. of CPE per year. In Time.
			47″	0° 0′ 0″	10″·728	0s·7152
				increasing to	decreas	ing to
B.C. 4697·072	90	79 15 46·21	28 51 55·3	12 16 57·62	0	0
				decreasing to	increas	ing to
A.D. 2294·75	180	0 0 0	23 25 47	0 0 0	10·728	0·7152
				increasing to	decreas	ing to
A.D. 9286·572	90	79 15 46·21	28 51 55·3	12 16 57·62	0	0
				decreasing to	increas	ing to
A.D. 18172·65	0	180 0 0	35 25 47	0 0 0	10·728	0·7152

Annual Difference (in Time) of Angle *CPE* for each Decennial Period from 1500 to 2400 a.d.

Year A.D.	Annual Diff.	Year A.D.	Annual Diff.	Year A.D.	Annual Diff.
	secs.		secs.		secs.
1500	0·69880	1810	0·70920	2120	0·71445
10	930	20	945	30	453
20	978	30	969	40	461
30	·70025	40	993	50	468
40	070	50	0·71016	60	475
50	114	60	039	70	481
60	156	70	061	80	487
70	196	80	082	90	492
80	234	90	103	2200	497
90	270	1900	123	10	502
1600	304	10	143	20	506
10	337	20	162	30	510
20	370	30	181	40	513
30	403	40	200	50	516
40	436	50	218	60	518
50	469	60	236	70	519
60	501	70	253	80	520
70	532	80	270	90	520
80	562	90	286	2300	520
90	592	2000	301	10	520
1700	621	10	316	20	519
10	650	20	330	30	518
20	678	30	343	40	516
30	706	40	356	50	513
40	734	50	369	60	509
50	762	60	382	70	505
60	790	70	394	80	501
70	817	80	406	90	496
80	843	90	417	2400	491
90	869	2100	427		
1800	895	10	436		

Annual Difference (in Time) of Angle *CPE* for each Year from 1850 to 1950 A.D.

Year A.D.	Annual Diff.	Year A.D.	Annual Diff.	Year A.D.	Annual Diff.	Year A.D.	Annual Diff.
	secs.		secs.		secs.		secs.
1850	0·71016	1875	0·71072	1900	0·71123	1925	0·71171
1	18	6	74	1	25	6	73
2	21	7	76	2	27	7	75
3	23	8	78	3	29	8	77
4	25	9	80	4	31	9	79
5	28	1880	82	5	33	1930	81
6	30	1	84	6	35	1	83
7	32	2	86	7	37	2	85
8	35	3	89	8	39	3	87
9	37	4	91	9	41	4	88
1860	39	5	93	1910	43	5	90
1	42	6	95	1	45	6	92
2	44	7	97	2	47	7	94
3	46	8	99	3	49	8	96
4	48	9	0·71101	4	50	9	98
5	50	1890	3	5	52	1940	0·71200
6	53	1	5	6	54	1	2
7	55	2	7	7	56	2	3
8	57	3	9	8	58	3	5
9	59	4	11	9	60	4	7
1870	61	5	13	1920	62	5	9
1	63	6	15	1	64	6	11
2	65	7	17	2	66	7	12
3	68	8	19	3	68	8	14
4	70	9	21	4	69	9	16
						1950	18

SECTION VIII

PROBLEM TO FIND DRAYSON'S DATA FROM RECORDED ORTHODOX OBSERVATIONS

In Section II. I have endeavoured to explain how and by what means Drayson ascertained his foundation data, especially the amount of the arc *CP*, viz. the distance between the pole of the earth and the centre of second rotation, and *CE*, the distance between the centre of rotation and the pole of the ecliptic. The above two arcs Drayson, by trial and error and possibly by somewhat rude methods, ascertained to be respectively 29° 25′ 47″ and 6° 0′ 0″. But whilst fixing the above amounts to the nearest second as the best approximation he could attain to the truth, by methods to which I cannot pretend to do justice without extensive references to his published works, he in later years admitted to me the possibility of those distances being more accurately determined and, I think, limited himself to a firm conviction that the distance between the pole of the earth and the centre of second rotation must be between 29° and 30°.

It occurred to me in 1894 that if by Drayson's data the obliquity of the ecliptic, the right ascension and declination of stars and other items can be found with much accuracy for any year, past, present, or future, it should follow that by reversing the process Drayson's data can be obtainable from Nautical Almanac and other recognised authorities. This I have endeavoured to do by six somewhat complicated calculations with the following stars—*α* Draconis, *α* Ursæ Minoris, *β* Orionis, and *α* Virginis, the results of which are given below in tabulated form. In that table it will be seen that, although the results vary, they all six point to a fairly

close approximation to Drayson's data, and the mean of the six calculations appears to me to be of some value. The six computations, although worked to decimals of a second, have no pretence to minute accuracy, which is unattainable with logarithms of not more than seven decimal places, and owing to the use of cotangents and cosines of very small arcs. The interval also between recorded observations is insufficient for the method adopted—no reliable records being, so far as I know, obtainable further back than 1820.

In addition to the table, I have added as an example the working in one of the computations, viz. that of β Orionis. I have said that the data used are orthodox, and obtained from the best records. There is, however, one small item which is not orthodox, viz. the correction of about $0^{s}{\cdot}7$ per annum correction of sidereal time applied to the Greenwich right ascensions to make them equal the angle *CP* star in the diagram. Some mathematical critic who may honour me by examining my figures may at once say that that unorthodox correction of time to some extent vitiates the method adopted. I admit the justice of such criticism, but in defence of my method I must plead a firm conviction that such error in the rate of sidereal time does exist, and that, viewing the correction which was found necessary in 1834, there is strong ground for believing that a fresh error has accumulated. Without allowing for that error it would have been impossible to triangulate the problem, as the angle *CP* star would not have correctly represented the right ascension of such star.

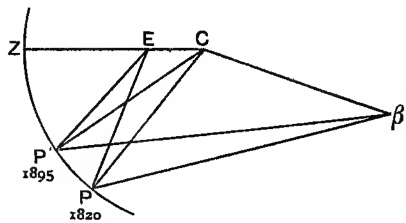
RESULTS OF SIX CALCULATIONS TO FIND DRAYSON'S FUNDAMENTAL DATA AND OTHER RESULTING ELEMENTS FROM OBSERVATIONS RECORDED IN THE NAUTICAL ALMANAC AND OTHER BEST AUTHORITIES, VIZ. NAUTICAL ALMANAC RIGHT ASCENSION AND DECLINATION FOR 1820 AND 1895 AND OBLIQUITY 1895, ALSO SIR GEORGE AIRY'S OBLIQUITY FOR 1840.

	CP Radius of Circle described by Pole of Earth round centre of Second Rotation.	*CE* Distance of Pole of Ecliptic from centre of Second Rotation.	Annual Motion (A.M.) of Pole of Earth on Small Circle.	Annual Angle (A.A.) at centre of Second Rotation.	Zero Year, *i.e.* year A.D. of alignment of centre of Second Rotation, Pole of Ecliptic, Pole of Earth, and of Minimum Obliquity.	Number of years in cycle of Revolution of Equinoxes.	Accumulated Error or Diff. of Greenwich Sidereal Time in 1892 since correction of 1834, assuming that no subsequent correction has been made.
α Draconis (1) .	29° 26′ 3″·25	6° 0′ 26″·5	20″·0852	40″·8714	2318·4	31709·2	41s·302
α Draconis (2) .	29 29 30 ·11	6 3 54	20 ·124	40 ·8779	2317·0	31704·2	
α Ursæ Minoris .	29 27 18 ·2	6 1 44	20 ·065	40 ·804	2323·3	31761·6	41 ·368
β Orionis . .	29 24 56 ·15	5 59 21	19 ·938	40 ·596	2325·8	31924·3	40 ·885
α Virginis (1) .	29 42 37 ·01	6 16 56 ·33	20 ·150	40 ·657	2300·6	31876·2	42 ·958
α Virginis (2) .	29 25 7 ·17	5 59 30 ·5	20 ·090	40 ·900	2319·0	31687·0	41 ·212
Mean of above results	29 29 15 ·31	6 3 38 ·72	20 ·0754	40 ·7844	2317·35	31777·08	41 ·545
Drayson's data .	29 25 47	6 0 0	20 ·0529	40 ·8114	2294·75	31755·8	41 ·283

The above results from the six calculations as previously stated in this section, although given as ascertained to fractions of a second, have no pretence to minute accuracy for reasons already stated. For instance, a difference of $1\frac{1}{2}^s$ or 2^s in right ascension and of 4″ or 5″ in polar distance might make a difference of no less than about 15′ in *CP* and *CE*.

It may be worthy of note that a distinguished astronomer, Mr. Stone, when Radcliffe Observer at Oxford, discovered that the sidereal time of mean noon in 1892 was erroneous to the extent of $41^s·51$. See Royal Astronomical Society's Notes of 9th March 1894.

DATA PROBLEM WITH β ORIONIS



As an example of the method I adopted to test Drayson's data, I give the following extract from my work-book of 1894-5, using two recorded positions of β Orionis (Rigel) in the southern hemisphere at an interval of seventy-five years between them, and an interval of fifty-five years between two recorded obliquities.

Given :—

R.A. 1820, Nautical Almanac .	5h. 5m. 53·56s.
South Polar Distance 1820, N.A. .	81° 35′ 0″·2
R.A. 1895, N.A.	5h. 9m. 29·458s.
South Polar Distance 1895, N.A. .	81° 40′ 36″·32
Obliquity 1840, Sir G. Airy . .	23° 27′ 36″·5
Obliquity 1895, N.A. . . .	23° 27′ 10″·41

Correction of right ascension for annual error $0^{s}{\cdot}711$ of sidereal time.

From the above data it is required to find :—

1. *CP* radius of second rotation.
2. *CE* pole of ecliptic to centre of second rotation.
3. Annual motion of pole (A.M.).
4. Annual angle at centre of second rotation (A.A.).
5. Zero year. Alignment of *C* and *E* and year of minimum obliquity.
6. Duration of complete cycle.
7. Accumulated difference or error of sidereal time from 1834 to 1892.

To find $CP\beta$.

R.A.	5h.	5m.	53·56s.
		+	47·68*
	5	6	41·24
	6		
$CP\beta$	0	53	18·76

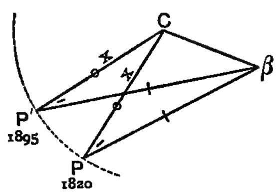
* Correction. $10''\cdot6747 \times \cdot67$ years.
$=11'55''\cdot205$
$=\ 47^{s}\cdot68$

To find $CP'\beta$.

R.A.	5h.	9m.	29·458s.
			5·698*
	5	9	23·76
	6		
$CP'\beta$	0	50	36·24

* $10''\cdot683 \times 8$ years.
$=1'\,25''\cdot464$
$=\ 5^{s}\cdot698$

To find Radius CP.



In the $\triangle\ CP\beta$

(1) $\operatorname{Cos} C\beta = \dfrac{\cos P\beta \cos (CP-\phi)}{\cos \phi}$ where $\tan \phi = \tan P\beta \cdot \cos CP\beta$

and in the $\triangle\ CP'\beta$

(2) $\operatorname{Cos} C\beta = \dfrac{\cos P'\beta \cdot \cos (CP'\beta - \phi')}{\cos \phi'}$ where $\tan \phi' = \tan P'\beta \cdot \cos CP'\beta$.

Let CP (which equals CP') $=x$

$P\beta = a$

$P'\beta = b$

$\phi \ = c$

$\phi' \ = d.$

Then from (1) and (2) we have †

$$\frac{\cos (x-c)}{\cos (x-d)} = \frac{\cos b \cdot \cos c}{\cos a \cdot \cos d}\ \text{(say)} = m$$

whence $\tan (x + \tfrac{1}{2}\overline{c+d}) = \operatorname{cotan} \tfrac{1}{2}(c-d) \dfrac{m-1}{m+1}$.

† In this equation the wily x at first eluded my efforts, and I was indebted to the kindness of Sir W. Niven, then Director of Studies at Greenwich, for its solution.

To find c.

$$\operatorname{Tan} c=\tan a\cdot\cos CP\beta$$

$$\begin{array}{r} 10{\cdot}8298457 \\ 9{\cdot}9881421 \\ \hline 10{\cdot}8179878 \\ \hline \end{array}$$

$c=81°21'14''{\cdot}01$

$$\begin{array}{ll} d & 81°28'21''{\cdot}6 \\ c & 81\ 21\ 14\ {\cdot}01 \\ \hline & 162\ 49\ 35\ {\cdot}61 \\ \hline \frac{c+d}{2} & 81\ 24\ 47\ {\cdot}8 \\ \hline & 7\ \ 7\ {\cdot}59 \\ \hline \frac{c-d}{2} & 3\ 33\ {\cdot}8 \\ \hline \end{array}$$

To find d.

$$\operatorname{Tan} d=\tan b\cdot\cos CP'\beta$$

$$\begin{array}{r} 10{\cdot}8347599 \\ 9{\cdot}9893262 \\ \hline 10{\cdot}8240861 \\ \hline \end{array}$$

$d=81°28'21''{\cdot}6$

To find m which$=\dfrac{\cos b\cdot\cos c}{\cos a\cdot\cos d}$

$$\begin{array}{lr} \operatorname{Cos} b & 9{\cdot}1606414 \\ \operatorname{Cos} c & 9{\cdot}1770486 \\ \hline & 18{\cdot}3376900 \\ & 18{\cdot}3365377 \\ \hline \operatorname{Log} m & 0{\cdot}0011523 \\ \hline \end{array} \qquad \begin{array}{lr} \operatorname{Cos} a & 9{\cdot}1654516 \\ \operatorname{Cos} d & 9{\cdot}1710861 \\ \hline & 18{\cdot}3365377 \\ \hline \end{array}$$

$$\begin{array}{rl} \therefore m= & 1{\cdot}0026567 \\ m+1 & 2{\cdot}0026567 \\ m-1 & 0{\cdot}0026567 \\ \hline \end{array}$$

Resuming the former expression to find x.

$$\operatorname{Tan}(x+\tfrac{1}{2}\,\overline{c+d})=\operatorname{cotan}\tfrac{1}{2}\,(c-d)\frac{m-1}{m+1}$$

$$\begin{array}{lr} \operatorname{Cotan}\dfrac{c-d}{2} & 12{\cdot}9844180 \\ \operatorname{Log}(m-1) & \bar{3}{\cdot}4243425 \\ \hline & 10{\cdot}4087605 \\ \operatorname{Log}(m+1) & 0{\cdot}3016066 \\ \hline \operatorname{Tan}\left(x+\dfrac{c+d}{2}\right) & 10{\cdot}1071539 \\ \hline \end{array}=\text{Log tan } 51°\ 59'\ 51''{\cdot}65.$$

Since $\dfrac{c+d}{2}=81°24'47''{\cdot}8$

$x+81°24'47''{\cdot}8=51\ 59\ 51{\cdot}65$

$\because x=51°59'51''{\cdot}65-81°24'47''{\cdot}8$

$$\begin{array}{rrrr} & 90 & 0 & 0 \\ \hline & 141 & 59 & 51{\cdot}65 \\ - & 81 & 24 & 47{\cdot}8 \\ \hline & 60 & 35 & 3{\cdot}85 \\ & 90 & 0 & 0 \\ \hline \therefore x= & 29 & 24 & 56{\cdot}15=CP \\ \hline \end{array}$$

To find $C\beta$.

$$\text{Cos } C\beta = \frac{\cos P\beta \cdot \cos (PC-\phi)}{\cos \phi}$$

Cos $P\beta$	9·1654516	$\phi = C$ as found above	$=81°21'14''·01$
Cos $(PC-\phi)$	9·7899399		29 24 56 ·15
	18·9553915	$(\phi - PC)$	51 56 17 ·86
Cos ϕ	9·1770486		
Cos $C\beta$	9·7783429	Whence $C\beta=$	53 6 40 ·1

To find $PC\beta$.

$$\frac{\text{Sine } PC\beta}{\text{Sine } CP\beta} = \frac{\text{sine } P\beta}{\text{sine } C\beta}$$

9·9952973
9·3627240
19·3580213
9·9029822
9·4550391

16° 33′ 59″·3

$\therefore PC\beta = 163 \quad 26 \quad 0 ·7$

To find $P'C\beta$.

$$\frac{\text{Sine } P'C\beta}{\text{Sine } CP'\beta} = \frac{\text{sine } P'\beta}{\text{sine } C\beta}$$

9·9954014
9·3404676
19·3358690
9·9029822
9·4328868

15° 43′ 14″·6
180

$P'C\beta = 164 \quad 16 \quad 45 ·4$

To find annual angle (A.A.) at C.

$$P'C\beta - PC\beta = PCP'$$

$P'C\beta$	164° 16′ 45″·4
$PC\beta$	163 26 0 ·7
$PCP'=$	0 50 44 ·7
$=$	3044″·7

$$\text{A.A.} = \frac{3044''·7}{75 \text{ years}}$$

3·4835445
1·8750613
1·6084832

Whence A.A. $=40''·596$.

To find annual motion (A.M.) of pole on small circle.

A.M. = A.A. × sine CP

Log A.A.	1·6084832
Log sine CP	9·6912060
	1·2996892

$\therefore$ A.M. $=19''·93835$

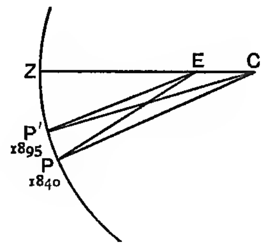
To find duration of cycle.

$$\text{Cycle}=\frac{360^\circ}{\text{A.A.}}=\frac{1296000''}{40''\cdot596}\qquad\begin{array}{r}6\cdot1126050\\ 1\cdot6084832\\ \hline 4\cdot5041218\end{array}$$

$\therefore$ Cycle=31924·33 years.

To find CE and zero year from above results and from obliquities of 1840 (Sir G. Airy) and 1895 (Nautical Almanac).

Given $CP=CP'$ 29° 24′ 56″·15
EP 23 27 36 ·5
EP' 23 27 10 ·41
$PCP'=40''\cdot596\times55$ years
$=37'\ 12''\cdot7$



First find PP' on great circle. (Shortrede, Case II.)

Cos PCP'	9·9999746		
Tan PC	9·7511480	Cos PC	9·9400581
Tan $P'C$	9·7511480	Cos $P'C$	9·9400581
Log x	$\bar{1}$·5022706	Log $(x+1)$	0·1198776
$\therefore x=$	0·317885366	Cos PP'	9·9999938
$x+1$	1·317885366		

From 0° 18′ 18″
To 0 18 26
(Say) PP' on great circle=0 18 22

Next find EPP'. (Shortrede, Case I.)

Cos EP'	9·9625528		
Sec EP	0·0374709	Co tan EP	10·3625249
Sec PP'	0·0000062	Co tan EP'	12·2722394
Log x	0·0000299	Log $(x-1)$	$\bar{5}$·8388491
$\therefore x=$	1·000069	Cos EPP'	8·4736134
$x-1$	0·000069	$\therefore EPP'=$	88° 17′ 40″·93

Next find *CPP′* and *CPE*.

CP′	29°	24′	56″·15			
CP	29	24	56 ·15		Cosec	0·3087940
PP′	0	18	22		Cosec	2·2722456
	59	8	14 ·3			
	29	34	7 ·15		Sine	9·6932573
	29	24	56 ·15			
	0	9	11 ·0		Sine	7·4267259
						19·7010228
					Cos	9·8505114

$$\therefore \frac{CPP'}{2} = 44°\ 51'\ 51''\cdot 4$$

CPP′	89	43	42 ·8
EPP′	88	17	40 ·93
∴ *CPE* =	1	26	1 ·87

To find *CE*. (Shortrede, Case II.)

Cos *CPE*	9·9998640		
Tan *CP*	9·7511480	Cos *CP*	9·9400581
Tan *EP*	9·6374751	Cos *EP*	9·9625291
Log x	$\bar{1}$·3884871	Log $(x+1)$	0·0950358
∴ x=	0·24461722	Cos *CE*	9·9976230
$(x+1)$	1·24461722		

$$\therefore CE = 5°\ 59'\ 21''$$

To find *PCE* (=*PCZ*) when *P* is at A.D. 1840. See last foregoing Diagram.

PE	23°	27′	36″·5			
PC	29	24	56 ·15		Cosec	0·3087940
CE	5	59	21		Cosec	0·9815474
	58	51	53 ·65			
	29	25	56 ·82		Sine	9·6914326
	23	27	36 ·5			
	5	58	20 ·32		Sine	9·0172330
						19·9990070
					Cosine	9·9495035

$$\text{Whence } \frac{PCE}{2} = 2^\circ\ 44'\ 21''$$

$$\therefore\ PCE = 5\ \ 28\ \ 42$$

Now to find zero year.

$PCE = 5^\circ\ 28'\ 42'' = 19722''$

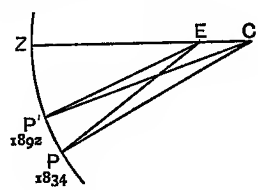
$$\text{No. of years } P \text{ to } Z = \frac{PCE}{\text{A.A.}} = \frac{19722''}{40''{\cdot}596}$$

PCE	4·2949510
A.A.	1·6084832
	2·6864678

∴ Years *P* to *Z* =	485·81
Do. A.D. *O* to *P* =	1840
Zero year A.D.	2325·81

To find the accumulated difference or error of the sidereal time of mean noon in 1892, assuming that the addition of $3^m\ 3^s{\cdot}68$ in 1834 was correct, and that no subsequent correction has been made. The data for this purpose are those found in the preceding calculation relative to β Orionis.

Given CP $29^\circ\ 24'\ 56''{\cdot}15$
A.A. at C $40''{\cdot}596$
CE $5^\circ\ 59'\ 21''$
Zero year 2325·81



1834

To find *PCE*.

$PCE = (2325{\cdot}81 - 1834) \times 40''{\cdot}596$
$= 491{\cdot}81 \times 40''{\cdot}596$

2·6917974
1·6084832
4·3002806

Whence $PCE = 19965''{\cdot}52$
$= 332'45''{\cdot}52$
$= 5^\circ 32' 45''{\cdot}52$

1892

To find *P′CE*.

$P'CE = (2325{\cdot}81 - 1892) \times 40''{\cdot}596$
$= 433{\cdot}81 \times 40''{\cdot}596$

2·6372996
1·6084832
4·2457828

Whence $P'CE = 17610''{\cdot}95$
$= 293'30''{\cdot}95$
$= 4^\circ 53' 30''{\cdot}95$

1834

To find P.

Tan $\phi = \tan CE \cdot \text{cosine } PCE$

9·0208296
9·9979623

9·0187919

$\therefore \phi =$ 5°57′40″·8
29 24 56 ·15

23 27 15 ·35

$$\text{Tan } P = \frac{\tan PCE \cdot \text{sine } \phi}{\text{sine } (CP - \phi)}$$

8·9872148
9·0164369

18·0036517
9·5999015

8·4037502

$P =$ 1° 27′ 4″·96

1892

To find P'.

Tan $\phi' = \tan CE \cdot \text{cosine } P'CE$

9·0208296
9·9984151

9·0192447

$\therefore \phi' =$ 5° 58′ 3″·02
29 24 56 ·05

23 26 53 ·13

$$\text{Tan } P' = \frac{\tan P'CE \cdot \text{sine } \phi'}{\text{sine } (CP' - \phi')}$$

8·9324148
9·0168847

17·9492995
9·5997936

8·3495059

$P' =$ 1° 16′ 51″·68

P in 1834 = 1° 27′ 4″·96
P' in 1892 = 1 16 51 ·68

10 13 ·28 = in time 40ˢ·885

Whence error of time in 1892 = 40ˢ·885.

Answers to Problem worked by β Orionis to find Drayson's data

1. CP radius of second rotation . . 29° 24′ 56″·15
2. CE pole of ecliptic to centre of second rotation . . . . 5° 59′ 21″
3. Annual motion of pole (A.M.) . . 19″·93835
4. Annual angle at centre of second rotation (A.A.) . . . . . . 40″·596
5. Zero year. Alignment of C and E and year of minimum obliquity . . A.D. 2325·81
6. Duration of complete cycle year . . 31924·33
7. Accumulated difference or error of sidereal time from 1834 to 1892 . . . 40ˢ·885

It should be clearly understood that the foregoing results are *not* obtained from Drayson's data, but are merely from my attempt to prove the substantial correctness of Drayson's system by officially recorded observations.

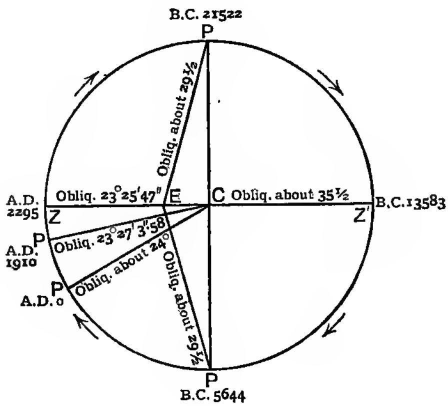
It should also be remembered that (for the reason before stated) my results in the above calculations, and those given in the foregoing table, have no pretence to minute accuracy.

For the purpose of comparison, I append the corresponding results obtained from Drayson's data.

1. 29° 25′ 47″
2. 6° 0′ 0″
3. 20″·0529
4. 40″·81143
5. 2294·75 A.D.
6. 31755·814
7. 41^{s}·283

SECTION IX

THE TEMPERATE AND GLACIAL EPOCHS



In the above cycle of about 30,000 years, I have termed the two halves of the cycle respectively the Temperate and the Glacial Epochs, and under such denomination it will be seen that :—

1. The last glacial epoch may be said to have commenced about B.C. 21,522, viz. about 23,500 years ago, when the obliquity of the ecliptic was 29° 25′ 47″.

2. The last mid-glacial epoch was about B.C. 13,583, viz. about 15,500 years ago, when the obliquity was at its maximum of 35° 25′ 47″.

3. The last glacial epoch terminated and the temperate epoch commenced B.C. 5644, viz. about 7500 years ago, when the obliquity was 29° 25′ 47″.

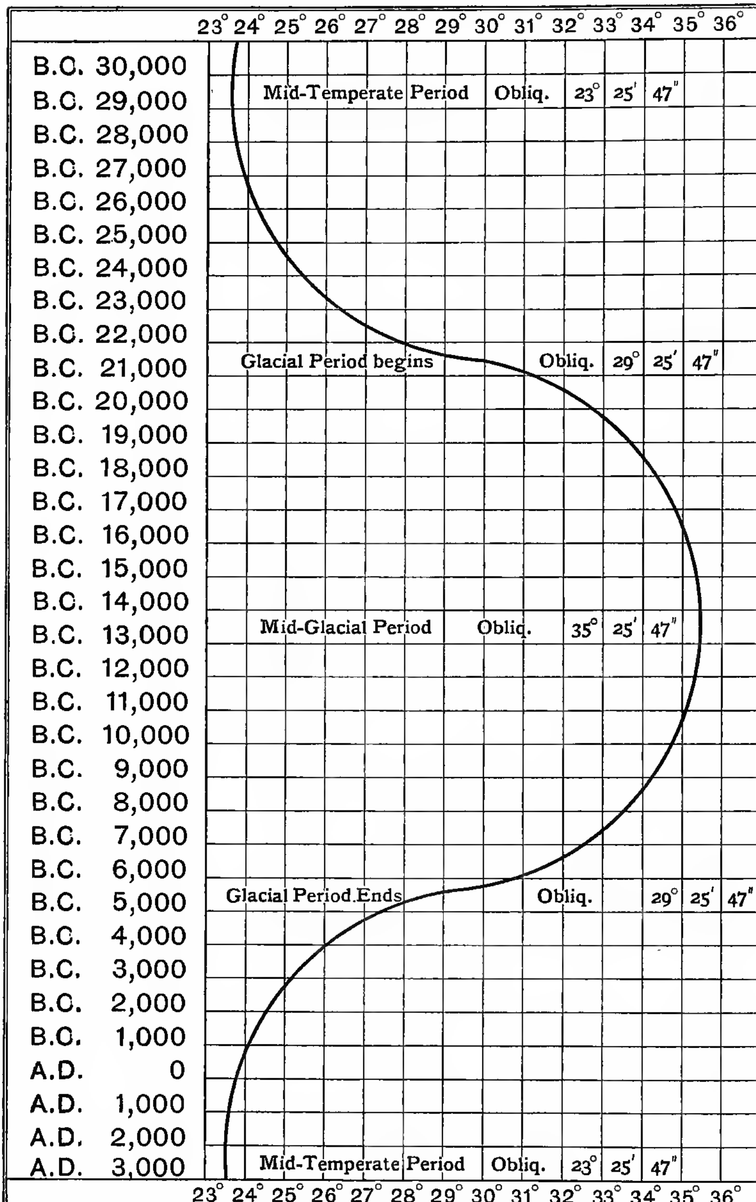
4. The next mid-temperate epoch, which we are now closely approaching, will be in A.D. 2295, viz. about 385 years hence, when the obliquity will be at its minimum of 23° 25′ 47″.

As the obliquity of the ecliptic will have been 35° 25′ 47″ at the mid-glacial period, it will be evident that the Arctic and Antarctic circles came down to about 54½° at that period, and thus reached respectively about the latitudes of Durham and Cape Horn. Similarly, the tropics of Cancer and Capricorn will have receded to a distance of about 35½° from the equator, (say) to about the latitudes of the Straits of Gibraltar in the north, and to that of the Cape of Good Hope in the south.

In order to give a more graphic representation of the changes in obliquity which have caused the alternation of temperate and glacial periods, I have constructed a diagram, which I have called the obliquity curve, for the period of a whole cycle. This curve may be of interest, as it shows at a glance how the glacial and temperate epochs have been determined by Drayson to have been caused simply by the increase and decrease of the obliquity. The diagram also shows that although the alteration in the obliquity is caused by the regular and unchangeable motion of the pole, amounting to 20″·0529 per annum, the annual rate of alteration of obliquity is variable; for instance, at the present time when approaching the mid-temperate epoch the rate of diminution is only about 0″·4 per annum, and is still a diminishing rate: whereas, at the beginning of the glacial period, when the obliquity was about 29½° the annual rate of increase was about 11″ per annum. Again, at the mid-glacial period the rate of increase of obliquity will have been reduced to 0, and at the end of the glacial period the rate of decrease of obliquity will have again increased to about 11″ per annum, as is evident by the steepness of the curve at the periods of change from temperate to glacial epochs.

THE OBLIQUITY CURVE DURING A CYCLE OF 31,756 YEARS.

Shewing the commencement, duration, and termination of last Glacial Period.



Facts connected with Astronomy and Geology

In 1896 Drayson wrote :—' Upon examining the writings of the older geologists it will be found that Ramsey, Lyall, Buckland, Agassiz, Darwin, Forbes, Murchison, and others give abundance of facts proving that this great change of climate occurred and produced what they termed " a glacial period."

' Modern geologists, among whom may be mentioned Professors Warren, Upham, Wright, B. K. Emerson, J. Prestwich, Dr. E. Andrews, and many others, not only corroborate the evidence of former writers as to such a glacial period having existed, but they affirm that the evidence is convincing, that this great change of climate ceased not longer than about 7000 years ago, and had lasted about 20,000 years. Sir Joseph Prestwich has long expressed his opinion that these dates as to the duration and termination of the glacial periods are proved by undeniable evidence.'

Such, then, are the facts resulting from Drayson's system, and granting, as admitted by geologists, and, indeed, universally, that a glacial epoch affecting both hemispheres has occurred in the past, the alteration in the obliquity of the ecliptic as described by Drayson appears to be the only admissible theory which can account, and that with the utmost simplicity, for such glacial epoch having taken place.

From the foregoing it will be seen that among the results of Drayson's discovery is the geometrical proof that the glacial period lasted only about 16,000 years or 18,000 years, and terminated about 7500 years ago.

The before-mentioned cycle of about 30,000 years, and the dates of the commencement and ending of the glacial epoch, can only be considered as correct for future ages on the supposition that the producing causes will remain unchanged. ' It would, however,' Drayson affirmed, ' be a fatal error to assume that because the second axis of rotation is now inclined to the axis of daily rotation at an angle of about 29° 25′ it must always have been so, and hence that during all past time there must have been successive glacial periods, is as

reckless as to assert that the earth's axis has always been fixed at a permanent angle of 66° 32′ to the plane of the ecliptic. As the centre of gravity of the earth varied, due to the elevation and depression of lands, and the consequent transferal of hundreds of millions of tons of ocean waters, so must the centre of gravity of the earth have varied, and consequently the angle formed between the poles of daily and second rotation, and hence the climatic changes during each second rotation.'

The announcement that the glacial period terminated about 7500 years ago was so entirely in opposition to the theories then believed in by geological authorities, who, instead of 7000 years, claimed hundreds of thousands and even millions of years, that General Drayson's accurate geometrical proofs were not only ignored, but the dates he gave became a subject for ridicule. During many years General Drayson had to submit to this treatment because he positively stated the above dates for the glacial period.

Of late years nearly all geologists in America and England have from geological evidence found that the dates given by General Drayson about thirty years ago were absolutely accurate. The position, therefore, which scientific societies subsequently occupied was that, although thirty years ago a proof was given them of the exact date and duration of the glacial period, they ignored or failed to comprehend the proof, and rejected the dates as absurd. After long years of research they found the dates formerly given by Drayson to be accurate, and appear to have claimed that this result is a modern discovery of their own.

The accurate determination of the date and duration of the glacial period, which has been described as a 'brilliant modern discovery due to geologists,' is a mere trifle in comparison to other portions of General Drayson's work. Before Drayson could so accurately give these dates he had discovered the cause of the glacial period, and had proved, by the most exact and hitherto unknown calculations, that the cause was correctly defined.

Having some eighteen years ago set to work to examine

and test Drayson's system (mainly, I must admit, with the idea of proving it untenable), and with a clear understanding that I should take nothing for granted, I found that my calculations based on his system enabled me to arrive at results exact to a second.

And here I may state that my old friend the late Major-General the Right Hon. Sir John Cowell, a distinguished Royal Engineer and able scientist, who with me was in the secret of Drayson's discovery, after full examination, entirely agreed with my conclusions.

I then examined the objections which had been urged against Drayson's system, and in no single instance could I find a flaw. As a proof that my conclusions are based on sound evidence, I may mention some of the calculations I made to find the obliquity, precession, and stars' polar distance and right ascension.

For instance, in the Nautical Almanac 1820, the right ascension of the star *beta* Ursæ Minoris was recorded as 14 h. 51 m. 20·36 s. for 1st January. The north polar distance for the same date was 15° 6′ 31″·8. From these data, and a knowledge of the true movement of the earth, calculate the right ascension of this star for the 1st January 1850, 1st January 1880, and 1st January 1895, also calculate its north polar distance for the same dates. Again: In the Nautical Almanac, 1825, the right ascension of the star *a* Virginis (Spica) is recorded for 1st January as 13 h. 15 m. 59·2 s. Its north polar distance for the same date was recorded as 100° 14′ 39″. From this one observation calculate the right ascension and north polar distance of this star for the 1st January 1875 and 1st January 1895. Again: Without reference to solar tables, or rule of thumb system derived from annual rates of change found by observation, calculate the mean obliquity for 1st January 1885.

I think I may assert that no one can make the above calculations unless acquainted with Drayson's system. I have made these and similar calculations, and my results differ from recorded observations less than one second.

From the carefully tested calculations I have made, and

which several others have made, I may say that such assertions as that 'competent authorities do not agree with Drayson'; that 'he is contradicted by the theories of La Place, Le Grange, etc.'; that 'he is merely giving another name to that which everybody knew before,' etc. etc., are reasonings not worthy of consideration. With all respect to the able astronomers above quoted, it is not reasonable to say that their knowledge was incontrovertible for all future time. For instance, the greatest scientists might, fifty years ago, have pronounced that it was impossible without telegraphic wires to hold conversations with persons hundreds or thousands of miles distant, and yet such pronouncement would in these days have been held invalid in the face of the marvellous discoveries of Marconi and other wireless scientists.

When we see the sound scientific base of these and similar calculations, and find that the facts of astronomy and geology are explained, and how exactly the two tell the same tale, it seems astounding that men claiming to love science for its own sake should ignore these facts. Every wild and baseless speculation to account for the glacial period has been put forward and solemnly discussed before scientific meetings, but after a very short time each of these has been found inadequate to explain the facts.

Here, however, we have a discovery which not only explains the facts, but gave the accurate dates of these facts thirty years before geologists, and in addition enables an average mathematician to make calculations hitherto unknown to astronomers.

That such an important matter should have been neglected during thirty years is bad enough, but when one small portion of it is claimed as a recent discovery by geologists, it is really the duty of every honest man to speak out.

It is interesting to note that Drayson, when writing to me 26th May 1901, said: 'Thirty years ago I sent the formula for finding the obliquity to Sir G. B. Airy (the then Astronomer Royal), and asked him to test it. He replied that it worked correctly, but that he had tried in vain to discover how I had framed it.'

When General Drayson announced that the hitherto accepted movement of the pole was a geometrical impossibility, that the true movement was a circle with a radius of 29° 25′ 47″ and not 23° 28′ as had hitherto been stated, that the centre of this circle was 6° from the pole of the ecliptic and had a right ascension of 18 hours, it is not surprising that he raised a storm of indignation which, had the old laws existed, would have placed him in the Inquisition, and thus have 'proved' him wrong. More especially would this have been his fate because he boldly told geologists that their dates for the glacial epoch were utterly wrong. That instead of this epoch having, as they imagined, lasted hundreds of thousands of years and terminated 200,000 years ago, it lasted only 18,000 years and terminated about 7000 years ago. Geological authorities were indignant, and refused even to listen to such heresy. Hence the leaders in both astronomy and geology refused to permit any further investigation of the facts, and even had the temerity to state that the matter had been fully examined and had been 'proved' incorrect.

Not only has no 'proof' ever been given against General Drayson's system which was worth even half an hour's examination, but proof after proof has been given of its accuracy. There ought to be no popery in science. When, however, we find that the only portion of this system, viz. the most simple, giving the date of the Ice Age, is at last comprehended, it is unjust and un-English for men to be given credit for discovering that which Drayson told them thirty years previously.

When, many years ago, Drayson submitted a paper to the Geological Society, in which he gave those very dates for the glacial period which are now found to be accurate, the Society pronounced that these were wrong. When he submitted the astronomical portion of his discovery to the Royal Astronomical Society and invited a discussion, his paper was suppressed.

CONCLUSION

In concluding this treatise, I feel that some apology may be due for what might be deemed too much self-assertion on my part. Although a lifetime at sea with, so to speak, a sextant in my hand, must have given me considerable knowledge of that small branch of astronomy termed Nautical Astronomy, it should be understood that I make no pretence to knowledge of that great science, or to being in any respect a scientist, but I do claim to have sound reasoning powers and to have done my best to exercise them. Let me further express the profound respect I have for astronomy, a science some knowledge of which is not only enthralling, but leads its students to a more just idea and appreciation of the marvellous works of the Almighty, works so wonderful as to be far beyond the conception of man.

It has grieved me to notice how little support, or even toleration, Drayson has received from the scientific world, and I feel that, if so little acceptance of Drayson's system has been accorded to him after half a lifetime's study of astronomy, I cannot expect much attention to my poor endeavours to explain and make his system known. I have written with small hope of engaging the attention of great astronomers, but I do hope to induce the younger generation, whose professional advancement is not dependent on blind adherence to text-books, and who may take an interest in fully examining and proving or disproving Drayson's system, to bear in mind that the astronomy of a hundred and fifty years ago, and its parrot-like repetition, is not necessarily perfect for all time.

The direct proof of Drayson's system is obviously difficult to establish, but as in criminal jurisprudence circumstantial evidence is in many cases more reliable because—unlike a

witness—it cannot lie, so in the case of Drayson's system there is the following circumstantial evidence to put forward, evidence which any person of ordinary mathematical ability can test for himself. The system enables such persons to ascertain by calculation the following results for any year, past, present, or future, without reference to the Nautical Almanac of the year required :—

1. The obliquity of the ecliptic.
2. The right ascension of any fixed star.
3. The declination of any fixed star.
4. The precession of the equinoxes.
5. The right ascension of a star from its apparent annual precession in declination if known.
6. And conversely, the apparent annual precession in declination from its right ascension.

The above calculations are, by Drayson's system, as I have said, within the competence of any person possessing such limited knowledge of mathematics as myself, and the results of such calculations can be tested, as they will be found to agree precisely with the amounts stated in the Nautical Almanac, which have been obtained by years of innumerable observations at Greenwich. I think I may claim that no astronomer, however able, can produce the above results without acceptance of Drayson's theory and data. In confirmation whereof, as I have previously stated, so great and distinguished an astronomer as the late Sir George Airy, whilst admitting the correctness of Drayson's formula, told him that he had tried in vain to discover how he had framed it.

Let me urge young students in search of the truth to test for themselves the accuracy of my claim on behalf of Drayson without reference to annual rate or rule of thumb, and to bear in mind a saying of Drayson's—in which I believe there is much truth—that in studying astronomy, old text-books had been his greatest obstacles.

Finally, I should add that in my eighteen years' examination of Drayson's system, I have from the first taken nothing for granted. Similarly, I ask those who favour me by reading these words also to take nothing I have said for granted, but

to study the matter for themselves, as I have done by patient research, and copying from my voluminous work-books and from my correspondence with Drayson up to the time of his death.

This work has been an enthralling relaxation since compulsory age retirement in 1892, after service in the Navy since 1840, including over twenty years' command of H.M. ships and squadrons at sea.

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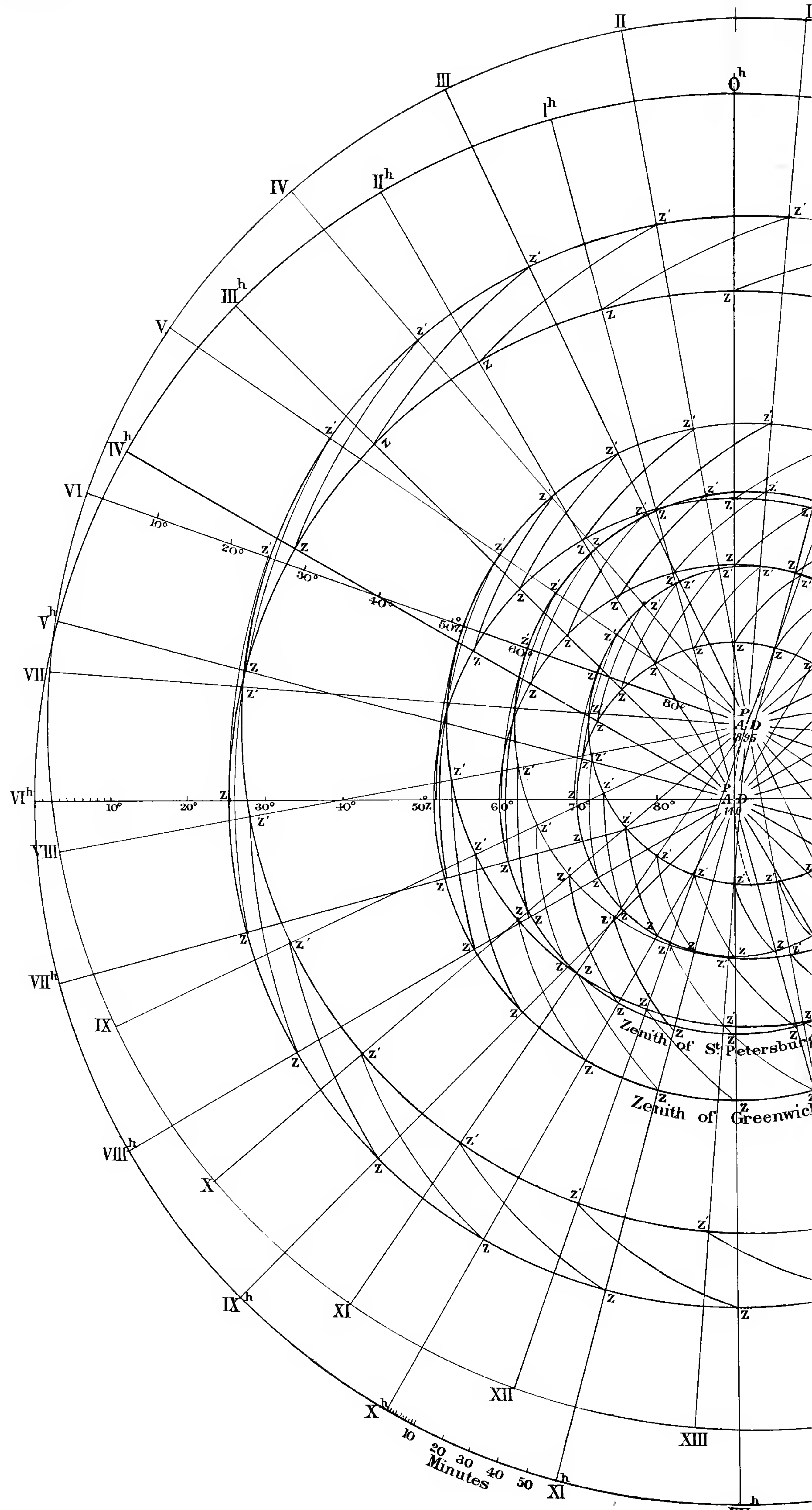

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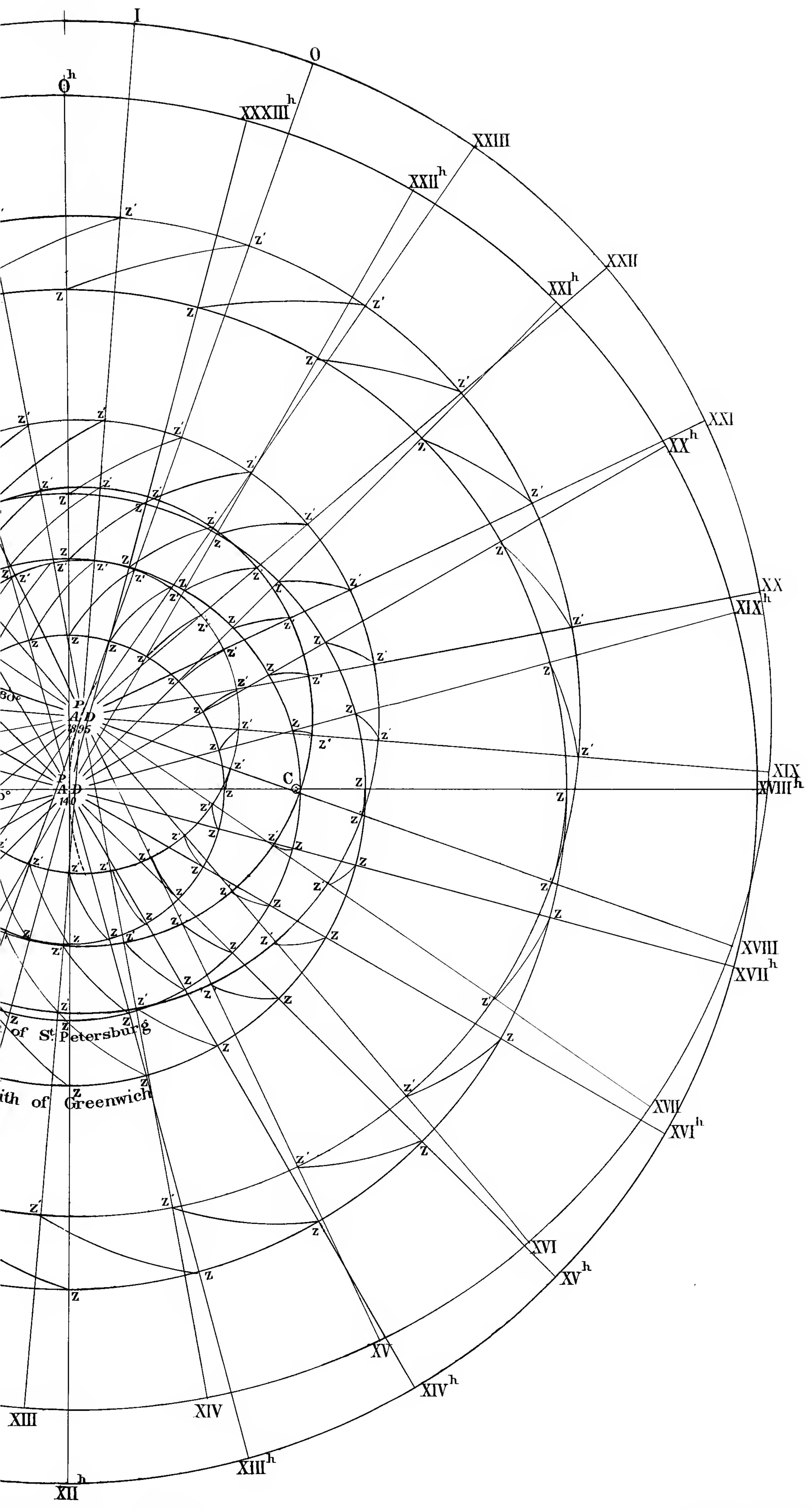

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